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RAILWAY TROUBLES

AND HOW TO FIND THEM

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Electric Railway Troubles

AND

HOW TO FIND THEM

A Comprehensive Treatise on Motors, Motor Operation, Motor Repairs, Car Break-downs, Control Systems, Repairing of Control, Air Brakes, Air Brake Troubles, and Electric Railway Operation Generally : : : :

BY

PAUL E. LOWE, M. E.

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PREFACE.

The value of constant vigilance, close attention to details, and the determination by diligent study and application to master the intricacies of the machinery and apparatus with which the electric railway operative is entrusted cannot be too forcibly urged. Economical and efficient operation are the fruits only of conscientious, and intelligent work. In some capacities, notably among them that of motorman, the necessity for careful and intelligent attention to his duties is particularly far reaching. The motorman should be capable not only of operating his car over the route with all of its apparatus in good working order; but he should also be a man full of resources, and determination, ready for the many emergencies liable to arise in the operation of an electric car. In order to furnish the student with a reliable guide and counselor which would enable him to act intelligently when the crisis comes, the following pages treating upon railway troubles have been prepared.

The best results deduced from the exercise of judgment and experience in the operating and repair of electric railway apparatus in the past, coupled with the more advanced knowledge of today, have been compiled and are now presented to the seeker after information. This applies more especially to motors, although quite a large space is devoted to air brake apparatus, and car heating and lighting also.

MOTOR OPERATION.

GENERAL INFORMATION FOR THE GUIDANCE OF MOTORMEN.

An overload of current is any amount in excess of the carrying capacity of the fuse in the circuit, and is produced by grounds or short circuits in wiring motors. To prevent an overload of current a fuse is used, which melts or fuses when an overload occurs on that circuit. An overload may also be caused by improper use of the controller or by lightning striking the line. Feeding too fast or reversing will cause an overload.

The fuse, which is usually composed of an easily melting composition, such as lead with tin, is placed between the second main motor switch and the lightning arrester, or controller, at which point the circuit is ruptured when the fuse melts and the equipment is thereby protected. If a fuse is made to carry 150 amperes, anything in excess of that will melt it. If a line has 500 volts' pressure and the motor becomes short-circuited, the ground, causing little resistance, the load will rise and the resistance being equal to two ohms, the amount of current passing this circuit would amount to 500 volts which, divided by two ohms, would allow 250 amperes of current to pass, or 100 amperes in excess of the carrying capacity of the fuse. The carrying capacity of fuses is indicated by stamping the number of amperes on one of the copper terminals. The composition part of the fuse should be bent, when inserting it, so that an air space may be left between the fuse and the face of the fuse box in order that the air may circulate around the fuse, which tends to minimize any rise in temperature produced by an overload of current.

A fuse of greater carrying capacity than is required should never be used. A 200 ampere fuse where the circuit of the motor only requires a 100 ampere fuse would expose the motor and controllers to damage. Currents retarded by the resistance points will cause the resistance coils to heat, and it is therefore injurious to run on resistance points. The resistance is used in circuit with a motor to avoid the full flow of current to the motor terminals, causing the armature to move too suddenly.

Resistance cores also termed rheostats or diverter coils consist of long strips of iron ribbon and are constructed in two forms—the panel form, insulated with asbestos between each layer; the other form is cylindrical, and the layers of the coil are separated by mica and asbestos insulation. Both mica and asbestos, being capable of standing high temperature, are valuable insulating materials, preventing the coils from being short-circuited and securing full resistance. When resistance fails or lessens, the current, instead of following its proper path, is carried to ground through a shorter course.

On the G. E. K or K-1 controller the safe running points are 3, 4, 6 and 7, and the resistance points are 1, 2 and 5. On the G. E. K-2 controller the safe running points are 4, 5, 8 and 9, and the resistance points are 1, 2, 3, 6 and 7. On the G. E. Ks-10, 11 and 12 controllers the safe running points are 5 and 9, and the resistance points 1, 2, 3, 4, 6, 7 and 8.

On the Westinghouse 28-A controller the safe running points are 4 and 7, and the resistance points are 1, 2, 3, 5 and 6.

The long bars on the dial plate indicate the safe running points and the short bars indicate the resistance points.

The motors take their numbers from their positions relative to the fuse box, No. 1 being the motor nearest the fuse box and No. 2 the one farthest away. Motor No. 1, in a G. E. controller, is cut out by throwing up the left-hand switch and Motor No. 2 by throwing up the right-hand switch.

Motor No. 1 in a Westinghouse 28-A controller is cut out by placing the handle of the bottom cut-out plug in a vertical position in both controllers. The bottom plug is the No. 1 plug, and the No. 2 plug is the top one. To cut out the No. 2 motor the handle of the No. 2 cut-out plug is placed vertically in, the controller being at the time operated.

When cutting out a motor or when inserting a fuse the overhead switch or circuit breaker should be thrown off, and a car should never be run with the power on and brakes partly set, as this produces heat in the armature and field coils, carbonizes and destroys the insulation, thus permitting the coils of wire to come in contact with each other and producing short circuits or grounds.

The General Electric and Westinghouse companies supply a controller interlocking device which prevents the operation of the controlling cylinder when the reverse handle is in the center, and also prevents the reverse cylinder from being thrown in either direction when controlling cylinder is in circuit.

Should a car equipped with a G. E. controller have a grounded controlling cylinder, both motors may be placed in series without resistance, and they may then be operated in either direction by setting the reverse switch and applying power to controller and from it to motors, by throwing the overhead switch on when wanting to start, and to the off position when wanting to stop. The motors are placed in series by operating the car from the rear controller or by wiring from trolley wiper No. 15 to wiper E-1.

If the car had entire resistance in circuit, motors in series and cylinder grounded, it should be operated by connecting a wire from trolley wiper to R-1 wiper and another wire from wiper No. 15 to E-1 wiper. The power should be by overhead switch and the direction of the car controlled by reverse switch. The trolley wiper is the one at the top of the wiper board of the controller in the G. E. type, and the one at the top of the controller in the Westinghouse 28-A type. The fifth wiper down from the top is the No. 19 wiper on a G. E. Type K or K-1, and on the K-2 the No. 19 wiper is the sixth one down from top of controller. On controllers K-10, K-11 and K-12 the No. 19 wiper is the seventh down. The wiper No. 15 is the sixth wiper down on the K or K-1 controller; the seventh wiper down on Type K-2 and the eighth wiper down on Type K-10, K-11 or K-12. On the G. E. Type K or K-1 the eighth or ninth wipers down from the top of the controller are marked E-1, and on Type K-2, K-10, K-11 or K-12 the ninth and tenth wipers down from the top of controller are marked E-1.

In all the G. E. types of controllers the R-1 wiper is the second one down from the top of the controller, and R-2, R-3, R-4 and R-5 follow down numerically.

In making these wiper connections care should be exercised to keep the wires from making contact with the controller casing or cover, and it is well to throw the overhead switch to the off position. The insulation on the wires should be perfect, removing sufficient, however, at each end to obtain good contact.

When it is necessary to connect the reverse contact wipers in pairs, proceed as follows: Connect together the third and fourth wipers; the fifth and sixth, and the seventh and eighth. The third and fourth, along with first and second, constitutes the connections of No. 1 motor; likewise, the fifth and sixth, and seventh and eighth, constitute the connections of No. 2 motor. In other words: Take the bottom contact wiper as No. 1 and connect it to the second contact wiper, or No. 2, up on reverse switch. In like manner the remaining six wipers may be connected in pairs. To obtain a cross connection, connect the bottom reverse wiper to the third wiper and the second to the fourth; this will constitute the connections of No. 1 motor. Then connect together fifth and sixth wipers and next sixth and eighth, which will constitute the connections of No. 2 motor.

Now, should a car using a G. E. controller have a grounded reverse cylinder, the car may be operated by throwing the reverse cylinder out of connection completely and then connecting the reverse contact wipers in pairs, as directed above, and a forward movement of the car can be effected, and the backward movement can be obtained by cross connecting the reverse contact wipers.

To protect the controller from ground, or short circuits, which might be caused by an arc held in the controller, a blow-out magnet coil is used in the controller. It is a device composed of a core wound with insulated copper wire or ribbon, and its function is to excite the pole piece in order to create magnetic lines of force for the purpose of breaking the arc when the controller is being thrown to the off position.

To operate a car when blow-out magnet coil is grounded, connect the negative and positive wires of the magnet coil together, thereby cutting it out of the circuit.

To prevent an arc from being blown out from one contact wiper to another, devices termed arc deflectors are placed between the contact wipers. On the G. E. controllers the deflectors are attached to the swinging pole piece of the controller.

When both overhead switches, or circuit breakers are thrown on to close a circuit, and controller is at off or normal position, a grounded blow-out magnet coil in either controller will cause fuse to be blown in circuit.

When motors are said to be in series it signifies that two motors are so connected in the circuit that the current flows through No. 1 motor, but must pass through No. 2 motor before completing its circuit. When motors are connected in multiple or parallel each motor is so connected as to be independent on its own circuit.

For a comprehensive knowledge of the numerous terms and phrases employed in the electrical profession, a study of the Electrical Dictionary will be found of great advantage to students and operatives; but there are a few terms which are so often met with in the daily routine of work that they are here briefly defined for the information of motormen.

A volt is the practical unit of electro-motive force which would cause a current of one ampere to flow through a resistance of one ohm.

An ampere is the accepted unit of electric current, or the current which could pass through a circuit that offered a resistance of one ohm under a one-volt electromotive force.

In street railway work, the usual voltage on the line is 500 volts. An ohm is the practical unit of resistance—a resistance such as would confine the electric flow under an electro-motive force of one volt to a current of one ampere per second.

The positive side of a circuit is the side connected with the positive pole of the source. The plus side of a circuit.

The negative side of a circuit is the side opposite the positive side—the side into which current flows after having performed a function—that side of a circuit which is connected with the negative pole of a source. The minus side of a circuit.

The pole pieces of a motor are the terminations of the cores of electro-magnets. They become magnets only when excited by the field coils surrounding them, and are therefore temporary magnets, ceasing entirely to act as magnets when the power is shut off.

Motors may have two or four pole pieces, which are referred to as the north and south pole, or poles, as the case may be. Two north and two south poles are necessary in a motor of four pole pieces to maintain evenly the polarity of the magnetic field in which the attraction and repulsion of the armature occurs, thereby causing the revolution of the armature, which, being connected by a gearing to the truck axle, causes it to revolve and propel the car.

The gear apparatus consists of a gear wheel and a pinion, the gear wheel being mounted on the truck axle and secured to it by a key, which is inserted into a groove cut partly in the axle and partly in the hub of the gear wheel, and also by means of bolts, both axle and wheel are held rigidly together.

In some instances the pinion is secured to the armature shaft by means of a key and nut on end of armature shaft; in other cases it is placed on armature shaft by expanding it with heat and allowing it to become rigidly fixed by cooling and contraction.

The cogs of the pinion, which is mounted on the armature shaft, engage the cogs on the gear wheel, which is mounted on the truck axle and the revolutions made by the axle are in proportion to the relative sizes of pinion and gear, and which is termed *gear ratio;* these ratios ranging, 3, 4 and 5 to 1, approximately, in the several types of motors. If the pinion cogs are 17, and they engage a gear wheel with 67 cogs, such a ratio would be designated as 4 to 1, since the pinion would revolve approximately four times to each revolution of the gear wheel; or, more definitely stated, the armature would move four revolutions to every one made by the car wheels.

APPLICATION OF POWER.—The power should never be applied too abruptly, as the current will rush in too great volume to the motor terminals and may cause short circuits in the motors, either on brush-holder yoke or armature circuits; or the current may, with such defects, back up in the controller, causing short circuits or grounds. The gears and pinions may also be stripped if power is applied too suddenly.

An emergency stop should never be resorted to except to avert accident, and when there is a failure of line power, and brakes are out of order.

In an emergency, it may become necessary to stop a car by the operation of the controller without the use of the line power or brakes. This may be effected by throwing the overhead switch to the off position, and the reverse handle in the direction contrary to movement of the car, and then throwing the handle of controller cylinder to the last parallel position. This causes the motors to produce a current by being held in opposite polarity; the stronger motor, or the one more affected by the strength of the magnetic field, becomes a generator and the weaker one, acting as a motor, is driven in the opposite direction. If the reverse switches were set for a forward direction with both controllers and the power applied from one end, the car could not be moved forward with either controller, and the fuse would be blown in circuit on the series positions with their controller.

If the reverse switch on No. 1 controller were set for forward, and on No. 2 controller for backward motion, the car would go forward with No. 1 controller on all positions, and fuse would not be blown.

With some makes of controllers, if the reverse switch is thrown on, a short circuit is produced in the controller and causes the fuse in circuit to burn out; it is also liable to produce short circuit in armature coils.

CIRCUIT BREAKERS.

Circuit breakers are placed at intervals in the overhead wire along the line, dividing the line into sections so as to confine any defect to the section affected, and line circuit breakers should not be passed with power on.

On each end of a car is an M. M. switch or circuit breaker to enable the motorman to conveniently open the circuit when necessary.

ELECTRIC TRACK SWITCH.

An electric track switch is a device employed to open or close a switch for certain directions and consists of an electro-magnet with an armature, having attached to it an inverted pendulum with a conical shaped apex. In the slide bar connected with the switch tongue point there is a recess into which the conical part of the pendulum falls and fits when the switch is operated. This switch is located between the two rails of the track below the street surface. The electro-magnet, of which the electric track switch is partly composed, may be described as a coil possessing magnetizing power, encompassing a soft iron core, which is susceptible to instant magnetization or demagnetization, when the circuit is opened or closed. A complete connection for the device is obtained by connecting the wire leading to the electro-magnet coil at one end to the insulated track, and the other end to the positive binding post of the electro-magnet, and attaching a wire from the negative side of coil to the return wire of the track.

CURRENT FROM the return circuit of the car motor is the power which operates the magnet. The switch is set for the right direction of the car; the trucks then pass over the insulated section of track, forming a connection with main return wire. When this connection exists the power must be shut off while passing over the insulated section, as otherwise the switch would be thrown.

A car should never be run at high speed over facing point switches, as the forward wheel is liable to throw the switch tongue and thereby derail the car.

When a car fails to operate by reason of the power being off the line, the controller should be thrown immediately to off position, and the lamp circuit turned on so that when power is turned on again it will be indicated by the glowing of the lamps. When power is restored to the line the cars on the line should be started in series of even, or odd car numbers, according to whatever may be the rule of the company, in order not to overload the line, which may cause the circuit breaker at the station to be thrown out, or by a fuse being blown, which would open the circuit again.

When the motors do not act in the circuit, the controller cylinder being thrown to the first position, the failure may be attributed to any one of several causes: A broken or short carbon brush; an open circuit in car wiring; the trolley wheel resting on line circuit breaker; a dead rail, or dirt between wheel and rail.

If the car wheel is standing upon a rail of which the bond that connects it to the adjoining rail has been severed, or if there is an accumulation of dirt between wheel and rail, the wheel will become insulated from the rail and open circuit will follow. In case of a dead rail a circuit must be formed from the dead to the adjoining rail in order to proceed with the car. When the open circuit is caused by dirt a circuit must be formed from the wheel to the rail. A switch iron jammed in between the rail and the wheel will form a circuit where dirt is the trouble, and an insulated copper wire may be used to form the circuit in case of dead rail.

Before using the switch bar, or wire when the car wheels do not make proper contact with the rail, try first to establish contact by rocking the car body. If this fails, then the switch bar or piece of wire may be used. In using the wire, select a clean place on the rail, and hold one end of the wire against this clean spot, and the other end against the wheel or truck. For a dead rail the wire should be used to connect it with the rail section.

It is well to look to No. 1 motor, or in the rheostatic circuit for a short circuit in motor circuit or car wiring if car does not move when throwing the power handle to first position and a flash in the controller occurs when throwing it off.

An open circuit may be caused sometimes by a brush or two not having been properly placed, or too tightly fitted in the brush holder, so that proper contact between the brush and commutator is not maintained by the springs. In such case remove the brushes and reduce them with sandpaper to fit readily in the brush holder.

If contact is not established when the controller handle is placed in the first notch and car fails to start, look for wear on both the contact surfaces of the drum and the finger, which may have been burnt away or overworn. In such case the burnt surface may be smoothed with sandpaper, and the contacts bent to assume their proper positions. If this fails the car should be operated with the other controller, the conductor handling the brake on the front platform and directing the motorman by signals when to stop and start until car can be run in for repairs. The car should be operated under such conditions at a very low rate of speed.

When a car does not start on the first contact, but starts on the second and acts normally thereafter, an open circuit may be found in the rheostat, or the first cable connection may be broken, or there may be an overworn controller with blistered or burnt contacts. Sometimes a rheostat is burnt—having received too great a current for a length of time—and the first contact terminal may be broken. The car will not then start at the first notch, and at the second it will jerk when starting. In this case move the controller handle a little beyond notch, or turn straight to the second notch.

When a loose or broken cable connection is discovered to be the trouble, place and fasten it in position. Usually it will be a cable connected to one of the motors, rheostat or lightning arrester, and not often in controller stand.

The controller cylinder cannot move beyond point 5 by reason of a stop on the controller spindle, with which a pin engages. The pin is operated by either of the cut-out switches when they are raised.

Should a fuse blow out upon the car starting, the lightning arrester may be grounded by foreign matter between the discharge points. This difficulty may be overcome by removing the dirt; or in the event that this cannot be done, the lightning arrester should be disconnected, the wire grounded and fuse inserted, as the difficulty is with the arrester. If the fuse is not securely fastened to its terminals, too heavy a load will cause it to blow out when the car starts. Heating and increased resistance are produced by poor contact caused by loose screws which hold terminals of fuse, and a quicker burning of fuse follows. The same effect follows if the field coil of a motor is grounded and fuse blows out when current is turned on; or if an armature or commutator is grounded; or if a field or armature is short circuited in a car equipped with motors permanently in parallel and the fuse blows out, cut out the defective motor. The motor cut-out switches are located at the lower end of the controller and by means of these the car may be operated with a single motor. When the motorman finds it necessary to cut out a motor, he will be enabled to do so by following the directions contained in the instruction card, which is to be found in every controller. On account of the difference in connection, the instructions are not identical for both controllers of the same car; but they are plain and easily understood. When operating a car with a single motor, start the car on point 1 and bring it to maximum speed on point 5.

Many bad effects may be caused with a comparatively lightly loaded car, if the brakes should be partly set or the space between brake shoes and car wheels clogged with dirt.

When a car stops and starts again, remove controller casing and examine for a loose contact finger at the controller or for a loose cable or wire. If the drum of controller is blistered, the finger of the affected contact should be cleaned and, if bent, brought back to its correct shape and firmly screwed in proper adjustment. If the trouble is not found to be with the controller it may be caused by a loose cable connected with the terminals of a motor and all the screws securing the cable, leading to armature, field coils and brush holders should be made tight and firm.

Should there be any trouble inside of the rheostat proper no attempt to remedy it should be made by the motorman, but the car should be gotten to barns and trouble there reported. Troubles of this character are indicated by car starting with a jerk and then running along smoothly. In such instances, a short circuit may be suspected in rheostat, and if the trouble is due only to crossing of the cables, or a loose cable in contact with another terminal, the irregularity may be removed by the motorman.

Dirt, moisture or other foreign matter in the controller will cause severe flashing and smoking. The same effect will be produced if controller is turned off too slowly. The remedy is to open the overhead switch and blow the foreign matter out from the ring terminals, and from the lower ends of controller and free it from all moisture.

An odor of shellac and burnt cotton would indicate the burning out of a motor field, or armature coil, and the short circuiting, or burning out of a field magnet coil would be indicated by an abnormal speed of motor. Cut out a motor thus affected.

The lamps on a car are connected in series, and if one is burnt out none will light up. When they do not light up on turning the switch, either the lamp circuit fuse is blown out or a lamp is burnt out or not screwed to contact in the socket.

Covered fuses are now almost universally used instead of the uncovered ones, as they are more sensitive and, again, the covering prevents an exposure of the arc when a fuse becomes ruptured.

By reason of the small area of contact surface at terminals, if the fuse is not adjusted to get the full contact it is liable to melt. The imperfect contact would offer high resistance and raise the temperature above the melting point of the fuse.

An open circuit on the field, or armature leads of a motor or any of its contact connections representing the leads of the motor will prevent the operation of a two-motor car on the series position; but the car may be operated on the parallel positions.

If the open circuit occurs in No. 1 motor, the controlling cylinder of No. 2 motor must be placed in connection with the first parallel position of the controller before that motor can be operated. If the open circuit occurs on No. 2 motor, to operate No. 1 motor the indicator pointer of the controller may be half way between the fifth and sixth positions.

Short circuits are caused by defects which permit the electric current to find a shorter circuit than is provided for by the system. When a short circuit occurs in any part of electric machinery, apparatus or mechanism, that part is at once deprived of its power to properly perform its functions; it becomes weakened or disabled, and when it occurs the motor affected should be promptly cut off, as the drainage is liable to increase, the longer the motor is kept in operation, and causes a strain upon the dynamo in the power station.

A short circuit may be caused by moisture or dirt penetrating the windings and cutting out a certain number of turns of the wire with which the magnet of the motor has been wound to increase its power. If out of 400 turns of wire, 200 turns have from this cause been cut out, the current will seek a path through the remaining 200 turns which are unaffected and normal, and thereby shorten the circuit.

Short circuits may also occur by the crossing of flexible wires connected to the motors, or they may be produced by rain, dirt and other causes.

All translating devices on a line, when in normal condition, offer a certain amount of resistance to the current in a circuit; but when impaired by any defect, they act as a conductor, offering but little resistance to the current between the two wires. On a trolley line, if the current did not pass properly through the motors, a direct connection would be formed between the trolley wire and the rail.

When a motor is grounded or there is a short circuit, the current has found its way to the iron core by reason of defective insulation, thus cutting out that part of the field or armature winding through which the current should flow before reaching the car wheel, and impairing the operation of the car to a degree in proportion to the seriousness of the defect. The car may move slower or faster than when in normal relation to the circuit. An earth connection would be caused by a guard, telegraph or telephone wire falling over the trolley wire and touching the ground. This would cause a short circuit, the same as one on the dynamo.

When a contact wiper becomes broken, or so badly bent that it cannot be restored to correct position, it should be temporarily replaced by one from the opposite controller on the car.

To raise a motor with its own power when dropped, cut out the suspended motor. When the dropped motor is on the rear end of car in that direction, throw the reverse switch ahead for forward motion; when on front end of car in that direction, throw the reverse switch for backward motion, using in either case only the first position on the controller.

If in starting out with a car the motorman should discover that the controller handle could not be thrown beyond the last series position, the trouble would be caused by a motor being cut out with cut-out switch, and this irregularity should have been discovered by the inspector —when there is one—and remedied before turning car over to the motorman. Where there exists no regular system of inspection, and the motorman makes the discovery he should at once notify the foreman, or whoever may be in charge.

After having made a stop at a crossing, and the conductor ahead flags the motorman to go ahead, or at any time when starting his car and the conductor is not aboard, the motorman should see that no passengers are getting on or off the car before he starts.

DANGER IN LIVE WIRES.

A wire may have fallen over the trolley wire and, whilst not reaching the earth and forming a ground, is heavily charged by contact with the trolley wire. Should this wire be touched with the bare hands in attempting to remove it, the balance of the circuit would be formed by the interposition of the person's body, and a ground would be established; the force of the circuit from the charged wire, passing through him with disastrous results. With the high voltages now used, and the uncertainty of insulation maintaining its properties when exposed to atmospheric changes, all wires should be treated as though they were bare of insulation when it becomes necessary to handle them, as in cases where live trolley wires break and fall into the street or where other wires fall across them. Sticks and ropes may be used to remove such wires; but the operation with bare hands should never be attempted. Ordinarily a construction man may handle a trolley wire with bare hands, as he usually stands upon a high wooden ladder which insulates him from the ground; but should the trolley suspension wires be connected to the iron poles without insulation between them, as is the case on some lines, where there is only one insulator provided between the trolley wire and the span, he should use the utmost caution not to touch the trolley wire, and the span wire attached to the iron pole at the same time; otherwise a connection through his body would be established from the trolley wire to the ground. So long as he touches one or the other alone, there is no danger; but should he touch the two the result would in all probability prove fatal.

In going down grades keep controlling cylinder thrown full to off position, brakes partly set and firmly held. By allowing the car to descend grades without power a considerable saving of electric energy and hence reduction in the cost of fuel may be effected.

In case of hot journal bearing, run car to nearest repair station. When running through dark stretches of road at night or in foggy weather, operate the car so as to be able to stop within the distance that can be seen ahead, as near as possible.

When rails are slippery from moisture, sleet or any cause the acceleration of speed should not be too rapidly made in order to avoid slipping of wheels, and when ice and sleet coat the trolley wire, preventing contact with trolley wheel, the wheel should be removed and the fork permitted to glide along the wire and scrape off the ice.

In starting out from car barns, motormen should be sure that they have the proper controller and reverse handles for the particular type of controllers with which the car is equipped; otherwise serious difficulties may ensue from improper fit of handles.

When an arc is maintained after fuse is blown, the main motor switch should be thrown off or the trolley wheel removed from wire.

When a car in motion executes a lateral swing or movement, a sprung axle may be looked for, caused probably by defective tracks, with recesses worn in castings, into which the wheels have dropped. In a case of this kind the car should be taken to the nearest repair station, allowing the wheels of the affected axle to slide. To accomplish this, make the wheel secure by lashing it to side of track, with that part of the wheel resting on the track which can be best adjusted to the gauge.

Flat wheels, and broken or chipped flanges on car wheels may to some extent be minimized by the exercise of care and vigilance on the part of motormen. By avoiding the striking of curves too abruptly, and keeping a close watch ahead for stones or other hard substances which may be on the rails ahead much injury to the wheels may be prevented.

FALLING OF A TROLLEY WIRE.

Very serious consequences may result from the falling of a trolley wire. If in running past cross-overs or switches the trolley fork should get caught in the frog and pull the wire down, or should the wire fall from any other cause, prompt and intelligent action must be taken at once by the motorman and conductor. The accident should be immediately telephoned to the depot, giving notice of the trouble and the location. If not too much of the wire is down, it may be cleared to one side sufficiently to allow the cars to pass; but upon continuing on the run some responsible person should be left on the spot to warn drivers of teams and others until the emergency crew arrives. To relieve the power station from the ground and keep the cars in operation, should the wire fall across the rail, the wire may be laid on any pieces of wood that can be found lying around. This will prevent a ground occurring again. The wire should in no instance be touched with the bare hand; but may be handled with a piece of wood or a coat.

It should always be borne in mind that the trolley pole is intended to follow, and not go ahead of the car, and therefore, before attempting to back a car, the motorman should see that the trolley pole is turned.

When it becomes necessary to run a car with a pole from which the wheel has been lost, a piece of wire should be strung through the axle holes in order to keep the fork a little further away from the wire, which will lessen the liability of the fork being caught in a frog, or at an anchor ear in the line.

The value of constant vigilance, unflagging attention to details and the determination, by incessant study and application, to master all the intricacies of the machinery and equipment to which the railway operative is entrusted, cannot be too forcibly urged. Economical and efficient operation are the fruits only of conscientious and intelligent work. No operative, in whatever department he may be employed, can render efficient and acceptable service who fails to develop these paramount qualifications. From the highest officer, all along down the scale in the order of importance, the necessity for these personal qualifications applies with equal force; so far as they refer to efficiency in the various occupations; but in some capacities, notably among them that of the motorman, the necessity is more far-reaching, as additional professional and moral obligations are imposed upon the motorman, by reason of the greater risk to human life and damage to valuable property, for which he is presumed to act as the immediate protecting and conserving agent.

To provide by treatise for precautionary measures against all the contingencies and emergencies which are possible to arise in the operation of electric cars would involve not only almost unlimited space, but an intimate knowledge of all the laws of chance, which it has not been given to any individual to possess, be his experience ever so broad and diversified; but such manipulation of the power and exercise of judgment in running as has been deduced from past experience should be firmly fixed in the mind of every motorman in order that he may act promptly, and intelligently in the routine performance of his duty. A motorman well trained in all the requirements thus far discovered, looking to safe and economical operation, is more likely to successfully cope with a new and unexpected situation or emergency than the shiftless and unthinking operator whose work is more mechanical than intelligent.

HINTS TO MOTORMEN.

The most important factor in the operation of a car, so far as the motorman is concerned, is the controller, and his first care should be to thoroughly master the science of controller management.

The controller is located at the extreme end of the car platform and is the most complicated device of all electric car equipment. It is by means of the controller that the flow of the electric current is regulated as it enters the motor and provides for a gradual starting of the car. The flow of current from the circuit, were there no means of controlling it, would enter the motor at full force, causing the car to start off at its highest rate of speed. The effect of such a start is manifest. The car would give a sudden leap forward, throw all of the passengers violently from their seats, as in a collision, and seriously damage the machinery by severe strain or breakage. To avoid this and start the car off gradually, a resistance is provided which takes up the full force of the current and conveys it gradually as needed to the motor until full speed is attained. Each notch as the controller handle moves out cuts out more of the current from the resistance and allows that much more to enter the motor, and finally, when the last notch is reached the entire resistance is cut out of the circuit and the current enters the motor at full force, and the car then attains its maximum speed.

When about to leave the car barns with a car the trolley wheel is first put on and the controlling handles placed in position on the stand. Before starting the brakes should be off and the canopy switches closed. To start, the car controller handle should be moved from the position "off" to the first notch, and as the car gets well under that rate of speed, move to the second notch, and then to the third, and so on to the last notch, when the car will be running at full speed. Do not move the handle from one notch to another until the car has attained the rate of speed equal to the capacity provided for by the preceding notch; and yet there should be no unnecessary delay in moving up from notch to notch. By a careful manipulation of the controller the car can be started and the speed increased up to its limit without any perceptible jar, as at all times, except when at full speed, the entire current passes through the resistance, which has been divided into the several sections, each one represented by a notch, and the manner of transition from one notch to another, which determines the increase or decrease of speed, also determines the evenness and smoothness of the car's motion and its freedom from violent jolts and jars.

In an emergency, where a sudden stop is imperative and the brakes fail, or the trolley comes off and the car is equipped with two motors, the motors may be brought to a standstill by causing an interaction between them. This is done by reversing and throwing the controller handle on the highest point of the controller. This, however, is a heroic measure which should never be resorted to except in a last extremity, as damage to the machinery is practically inevitable.

There is no need of modifying the movement of the handle from whatever position it may be, in cutting off the current. Swing the handle around to "off" promptly. The reverse lever should never be used when a car is running, unless it is necessary to prevent an accident; in that case the current should be quickly cut off with the left hand, at the same time applying the brake with the right hand, then as quickly as possible throw the reverse lever and turn on current; but not too much; otherwise the wheels will slip and spin backwards and the car will not come to a stop within the same distance as if the wheels had maintained their adhesion to the rails.

When approaching a heavy grade run your car at maximum speed, so that when you begin the ascent the impetus will help the car up the grade without the necessity of so much current, as it requires a great volume of current to ascend a steep grade from a standstill. When the wheels slip on the rails, and especially in wet weather, the sand should be used in sufficient quantities to meet the difficulties; but with good judgment, nevertheless, in order that the supply may not become exhausted at remote points where it cannot be renewed. It is very necessary that the sand used should be well dried, and especially when the rails are wet and slippery. The car should be reduced to a low speed, and the brakes gradually set before going down a steep grade. When the descent is begun, see that the trolley is on the wire, the controller handle placed at "off" and the brake in position for instant use. The brakes must be kept applied unless the wheels begin to slide, in which case the brakes may be turned off a little until the wheels take hold of the track, and then set the brakes again; but should the brakes fail to work, reverse the motors. Should the trolley jump the wire, cutting off the power, bring the car to a stop by reversing and throwing the controller handle to the last notch.

Unless from some unavoidable cause, the car should never be stopped on a curve, and the power should be turned off when approaching curves or turnouts; but applied again upon reaching the curve, just sufficiently to carry the car around. Should the trolley jump the wire in turning a curve, the conductor should signal the motorman with the trolley rope from the rear platform, and the motorman should promptly swing the controller handle to "off," holding it there until signaled to go ahead.

Sometimes the power gives out, caused by an open circuit on the line. In that event all the other cars will experience the same trouble. When this occurs, swing the controller handle to "off," close the lamp circuits, and when the lamps light up, the car should move with the controller handle at the first notch; but if the car does not move it may be that the fuse has blown or burnt out, and in that case open the head switch or, preferably, tie the trolley pole down and replace the fuse. Should the car then refuse to move, the trouble must be sought for elsewhere. It may be that the car has become insulated from the rails by an accumulation of dirt, in which instance the difficulty may be overcome by the conductor forcing the end of the switch bar between the rail and the wheel and the motorman starting the car at the same time.

It is advisable to always keep a few yards of wire in the car in case of difficulty occasioned by a dead rail, although this is an occurrence rarely experienced. When, however, it is met with, the remedy is to place one end of the wire on the rail at the power station end of the car and the other end on some exposed part of the iron truck, always using care to avoid shock by placing the first end on the rail.

When the motors buck, and which is indicated by jumping motion as the car moves along, cut out the affected motor. The motor switches, by which the motors are cut out, differ somewhat in the various types of motors; but the well informed motorman will have familiarized himself with the type of motor which he is operating. When a car is at rest in the car barn the trolley should be tied down a little distance below the wire, the controller handles should be removed and the controller placed at "off." If for any reason the trolley should be left on the wire when the car is in the barn some of the car lamps should be turned on as danger signals for repair men.

Open the main or overhead switch when examining motors, and exercise great care that no water may drip into the motors from the wet clothing. Unless the overhead switch is open when the motors, fuse, etc., are being examined, shocks are almost certain to occur. No foreign materials, such as tools, waste, clothing, etc., should ever be permitted to remain on the side below the seat where are located the motor cut-out wire cable which connects controllers and motors. This place should always be kept free from moisture and rubbish of every description. No irregularities, when operating a motor, are too trivial to be noticed and investigated. Unusual sounds about the car may proceed from defect in the equipment which, if not located and remedied, may lead to serious damage. Bolts and other fastenings which become loose by constant jarring should be noted as soon as discovered and promptly reported, in order that the entire equipment may be kept always in good repair, thereby insuring better and longer wear, which makes for economy in operating expenses, and more efficient service. The same vigilance in observing any defects in the roadway, or on the line above is likewise incumbent upon both the motorman and conductor. While operating a car on the road the motorman should never remove his hand from the controller handle except under unavoidable circumstances, and he should never leave the platform of his car without first turning the controller off and removing the handle, as mishaps from neglect to take these precautions would be frequent and often attended by disastrous results. When the motorman is at his post with controller in hand, both the passengers and company's property are safe, for in case of a jam on the platform occasioned by passengers crowding on or off a car, should the handle be moved by someone in the rush and the car started, the motorman would be in position to bring it quickly under control; but should he happen to be off the platform, and the handle had not been removed, the car would start off without any control, and such a mishap could terminate with results varying from trifling to very serious damage to person and property. Usually there is someone at the power station whose duty it is to keep the car in proper working order for the motorman; but it is advisable for every motorman to be sure that everything is in readiness before starting on his run. The brushes and brush springs should be in position and the controllers should be at the "off" position before the trolley is placed on the wire. The trolley pole should always be placed in the right direction when car is running, i. e., pointing in the direction opposite to that in which car is running, otherwise trouble would ensue, as the pole, if pushed ahead instead of being drawn along with the car, would be apt to bend or break in coming in contact with any resistance and also cause trouble to the wire overhead

MOTOR REPAIRS.

Prevention of motor failures is the most important problem before a well organized maintenance department in electric railway service. The real purpose of the mechanical department is to reduce the number of breakdowns, and if possible to avoid them altogether. The necessity of efficient shop force and equipment can be readily appreciated when broken apparatus is brought into the shop to be repaired. The need of careful inspection of the vital parts of a direct current railway motor turned in for repairs is paramount, notwithstanding the long service and good name for reliability which it has earned.

Motors running on a division—if continued efficient performance, and a high motor mileage is expected—must be given careful and constant observation. It is well said that when the commutator's troubles are wiped out, 75 per cent. of the defects will be remedied. The importance of giving the commutator the greatest and closest attention has been emphasized many times. Some of the reasons which help to lower the records of individual motor equipments are due to the failure of inspectors to measure up to the requirements. Following will be found a few of the tending causes, which not only increase the cost, loss of time from service, but interrupt the flow of traffic on the lines: Gummy and sticky brush holders; incorrect spacing of brushes; the tension of brushes being at times uneven; low bars or high mica; loose leads, and carelessness in the handling of armatures in the shop. It is much better to send in a commutator to be turned a little too often than to have failures in other directions.

The weight of armatures of some modern motors is more than half a ton each, and too much of this weight should not bear upon the individual commutator bar, otherwise distortion is likely to result.

The tendency of fiber pieces to crack when subjected to long continued heating makes the use of canvas pads preferable. In this connection loose field coils can probably be better removed. Grounded and short circuits are often due to the looseness of field coils. With a view to overcome these irregularities that seem to be inherent in the commutator, the following method has been tried on a small scale: The commutator has been heated to the point where the varnish becomes fluid and then subjected to a twenty-ton pressure. This has been effective in forcing out the surplus varnish, and tightening the assembled structure, and thus far the service by this treatment has been greatly lengthened. The service reliability on different roads, and the number of factors that enter into the equipment life problem, is so great that there is considerable room for more than a little experiment along these lines.

REPAIRS OF MOTORS, CONTROLLERS AND CAR EQUIPMENT.

The principal items of repairs for motors, controllers and miscellaneous parts of car equipment are as follows:

MOTORS.

Replacing motor.
Replacing motor frame.

Making screw connection.
Making soldered connection.
Replacing armature.
Replacing field coils (each).
Replacing and adjusting brush holder and brushes.
Replacing and adjusting brush holder yoke.
Replacing brush spring.
Replacing connecting board.
Replacing dust pan or cover
Replacing armature bearings and fitting same.

CONTROLLERS.

Taking out drums and replacing same.
Taking out wipers and replacing same.
Taking out springs and replacing same.
Taking out caps and replacing same.
Replacing defective handles.
Re-shaping bent covers.

Blowing out and inspection of connections in controller, canopy-switch, fuse box and cut-out box.

Exchange drum.
Exchange reverse.
Exchange top (cast iron).
Exchange pawl (in addition to drum).
Exchange foot (in addition to back).
Exchange back.
Exchange blow magnet coil.
Exchange and fitting broken cover.
Replacing and adjusting wiper.
Replacing and adjusting back-spring.

MISCELLANEOUS.

Replacing diverter.
Replacing diverter spool.
Cables (under car).
Stripping frame.
Assembling frame.
Cleaning and painting.
Replacing worn out wheel and spindle.
Replacing worn out rope.
Replacing pole.
Straightening pole.
Replacing base.
Replacing canopy switch.
Replacing canopy switch handle.
Replacing fuse box.
Replacing fuse box plug.
Replacing cut-out box.
Replacing cut-out box plug.
Replacing three light cluster and lamps.
Replacing single socket and lamp.
Replacing lamp switch and plug.
Replacing pinion (arm in place).
Replacing gear (under car).
Replacing gear pan.
Putting gear on axle when removing from car.

A cardinal feature to be considered in the treatment of motors is the maintenance of the insulation to the highest plane of efficiency. It is only when the insulation is perfect that the current will flow through the motor along the proper paths and thus insure successful operation. All materials employed for insulating purposes should be subjected to practical tests by heat to determine the degree of temperature which they will stand without breaking down or losing their insulating properties. The maximum temperature which a motor will stand without the insulation becoming impaired, and the life of the motor being shortened is 40° Fahr. above surrounding atmosphere, or in net terms, 129° Fahr. in winter and 143° Fahr. in summer under working conditions. The insulation between the field coils and their cores, and between the armature coils and the body of the armature will become carbonized at a higher temperature. The effect of raising the temperature of a motor too high tends eventually to break down the insulation completely, by charring the cotton insulation and covering on the windings, and neutralizing their power of resistance to the stress which the windings are subject to when the controller opens the motor circuit.

In fact, the whole science of successful motor repairing lies in the proper manner of insulation; beyond which there is little else to cause deterioration in the motor except the inevitable mechanical wear on commutator and bearings.

INSULATING COMPOUNDS.

The Insulating Compounds now in general use may be classified as follows:

Air drying varnish and baking varnish.

Air drying varnish is composed of linseed or other drying oils with such treatment and driers as to become dry without baking in a few hours' exposure to the air. When dry the varnish should show a smooth, flexible surface; it should be moisture, and oil proof, and should not crack or soften at 100°C.

Spirit Varnishes are composed of animal or vegetable gums, shellac, copal, etc., dissolved in spirits, alcohol, amyl, acetate, benzine, etc. These varnishes are oil, but not moisture, proof and while they make good stickers and binders, they will soften at 100°C.

Baking Varnish is composed of linseed oil, or other drying oils with gum dryers, and requires baking for 10 to 12 hours at 100°C to 110°C. These varnishes possess high insulating qualities, they are good fillers, oil and moisture proof, have a high melting point, are very flexible and show a smooth, glossy surface.

No varnish should be used on a string band or webbing covering the mica at the outer end of a commutator which will not stand a temperature of 100°C without softening.

Insulating Paints are composed of solutions of asphalt and mineral gums in carbon bisulphide, naphtha, etc.

IMPREGNATING COMPOUNDS are of several varieties, and possess characteristics suitable to the various purposes for which they are employed.

Paraffine is used for impregnating wood for outside work in low temperature. It is a mineral gum which melts at a low temperature and is unsuitable for railway mechanism which operates at a temperature above 60°C.

Linseed Oil is largely used for filling the wood-work of railway apparatus, as the oil hardens under temperature, never melts, is flexible and strong, and proof against moisture and oil. Wood treated with linseed oil should be boiled in the raw oil, and when filled it should be baked to oxidize the oil. It may then be finished with either a baking or an air-drying varnish. For out-door work no better treatment of wood has been discovered.

Asphalt Compounds vary in their susceptibility to temperature, melting at different degrees of heat. The use of asphalt whose melting point is below operating temperature or 110° C, is inexpedient. At melting point the compound should flow freely; but at ordinary temperature it should become pliable only. This compound has fair insulating qualities, makes a good filler, and is moisture proof; but not oil proof. A good penetrating asphalt compound may be obtained by restricting the constituents insoluble in carbon bisulphide (CS_2) to a maximum five per cent.

TESTS FOR INSULATING COMPOUNDS.

All insulating materials should be tested with a view to determining their respective values and serviceable qualities. This may be done by a few simple processes and with sufficient accuracy, without the aid of elaborate accessories and apparatus.

Paraffine. The presence of water in paraffine will be indicated by foaming and sputtering on reaching the boiling point when the material is subjected to heat. The presence of sulphuric acid may be detected in two ways, viz.: by mixing the paraffine with boiling water, pouring off the water and testing with litmus paper, or by dipping into the paraffine a strip of bright copper. As water and sulphuric acid are both liable to be left in the paraffine from the process of refining this test should always be made.

Shellac. The presence of acids may be detected by the immersion of strips of bright copper. To determine the exact quantity of resin contained in shellac, involves an elaborate process not provided for in these simple tests. More or less resin is present in all shellac and whilst the exact quantity may not be determined, the working quality of the shellac may be ascertained by the simple expedient of applying a coat of different shellacs to a piece of bright tin, and comparing them to determine their relative flexibility. A very flexible shellac contains little or no resin.

Linseed Oil. To detect the presence of acids which are used during the process of refinement, strips of bright copper are allowed to remain immersed for several days in the oil.

The presence of water in the oil is indicated, when the oil is heated to boiling point, by a foaming and sputtering. Sometimes the oil contains a sediment termed "foots." To determine approximately the amount contained a small quantity of the oil is allowed to stand for about a full day in a test tube, and from the amount of sediment deposited the relative proportions may be determined.

Japans and Varnishes. The presence of acids should be tested with a strip of bright copper. The flexibility of the coating can be determined after it has been thoroughly dried by baking or exposure to the air, according to the treatment called for in each case. The testing temperature should be that to which they will be subjected in ordinary service.

Asphalt. The melting point of asphalt—and which is the main thing to be considered—can be determined with a thermometer. The melting point of asphalt may be low, or very high according to the nature of the material.

When the melting point is very high the material approaches the constituency of anthracite coal.

To determine the approximate amount of inorganic matter contained in asphalt—and some asphalts contain as much as 30 per cent—a certain quantity of the asphalt should be melted in crucible, or gas flame, until burned away, leaving a residue of inorganic matter, which by comparison with other similar tests of asphalt will determine the relative quantities contained.

The presence and proportion of sulphur in asphalt may be detected by melting the asphalt, and immersing bright strips of copper. After remaining in the melted material for two or three days the tarnishing of the copper will disclose the presence of the sulphur and approximately the quantity by the varying degrees of action of the sulphur upon the copper strips.

MOTOR REPAIRS OR TROUBLES.

There are several very common irregularities occurring in motors, the immediate results of which are indications which will enable the operative to locate the trouble at once. These irregularities are as follows:

Grounded armature, grounded commutator, grounded field, weak field, grounded brush holder.

Grounded Armature. When this trouble occurs the cause may be looked for in the armature coils, one or more of which have become in metallic connection with the armature core or pole piece. The presence of the ground will first be announced by the blowing of fuse in circuit, and the location is indicated by the controller, i. e., the fuse will be blown on the series positions when the trouble is in armature circuit of motor number 1, and the fuse will be blown on the parallel portions when the trouble is in armature circuit of motor number 2; providing, however, that the cut-out switch of each motor is holding it in circuit.

Grounded Commutator. When this trouble occurs the cause will be found to exist in a metallic connection having been formed between the frame which supports the commutator and a segment or segments of the same, and results from an accumulation of grease or carbon dust extending from the outer edge of the commutator to the shaft of armature, forming a short circuit and causing fuse to be blown in circuit.

Grounded Field. When this trouble occurs the cause will be found to exist in a metallic connection between the field coil and motor frame at some point, and the fuse is blown into circuit if the greater part of the field circuit is cut out by the ground. If the trouble is located in the field circuit of motor number 1 the fuse will be blown on the series positions, and if located in field circuit of motor number 2 the fuse will be blown on the parallel positions of controller, providing the cut-out switch of each motor is holding it in circuit.

Weak Field. This trouble is due to carbonized insulation causing on its own circuit a partial short circuit. The trouble may be located in either motor, and the fuse is blown out when controller handle is at the last running position. The trouble may also be detected when the current is first applied and the handle of controller is at first position, by a retarded movement of the car followed by a sudden acceleration of motor speed.

Grounded Brush-Holder. This trouble is due in some instances to the brush-holder yoke becoming carbonized, or the formation of metallic cônnection between the brush-holder frame and the motor frames. When this connection is formed in motor number 1 the car cannot be operated in any direction, and when controller handle is on series positions the fuse will be blown. When the connection is formed in motor number 2 the car can be operated on the series positions of controller, the fuse being blown on the parallel positions. When the grounded brush-holder is due to carbonization the trouble may be located in either motor, and the fuse will be blown when controller handle is on last position. To locate the motor affected, motor number 1 should be cut out and the circuit of motor number 2 tested with controller on series position. With this test the ground will appear in motor number 1 if the fuse is not blown; but if it is blown, then a test should be made in same manner with circuit of motor number 1 by cutting in that motor and cutting out the other.

Short Circuit at Shunt Connection. When this trouble occurs, caused by wires F1 and F2 becoming short circuited with each other, and the switches of both motors hold them in circuit, the car cannot be operated in either direction and the fuse will be blown when controller is on series position; but by cutting out either one of the motors the car can be operated in both directions.

THE FIELD WINDING.

Double cotton covered wire is the standard winding for the fields of all electric railway motors, and where the wire is insulated with asbestos and then cotton over that, this double insulation serves to prevent adjacent layers of wire from short circuiting the turns around the field, should the cotton become charred, as the asbestos will still offer sufficient resistance. Regardless of the various methods of field winding, the same liability to accident is common to all motors and the same care should be exercised in the winding—whether the field is wound on forms, field spools or any other method—to maintain the insulation at the highest plane of mechanical utility. Several treatments of the coils have been applied with varying results. The application of varnishes, especially shellac, containing wood alcohol, to each layer of wire, has met with only indifferent success, owing to the difficulty of drying out the coil and the tendency of the cellulose in the cotton winding to carbonize when the alcohol becomes oxidized. A method of insulation which has been found very efficient is to wind the field coils dry, warm them well and then dip them into a bath of some good insulating varnish. By this method the varnish will be thoroughly absorbed, penetrating and filling all the interstices and form an insulation which will resist moisture and keep the coils dry. After dipping, the coils should be hung up and allowed to drip until completely dried out. After the coils are dried out there are various methods of completing the insulation. One of the best is to cover the coil with micanite or mica, overlapping this covering to provide against seams; then wrap twice with adhesive tape, cover all with canvas, and finish with a coat of approved air-drying asphaltic insulating varnish. Before the fields, prepared by this process, are used they should be subjected to sufficient heat (by baking) to dry out effectually all solvents used in the insulation.

An approved method for insulating a field coil when wound upon the core directly is to insulate with mica, canvas and duck. When the field coil is completed the edges of the insulation are lapped over and then wrapped with adhesive tape following the direction in which the wire was wound. By allowing the insulation to project beyond the field coil, while in process of winding, the overlapping can be neatly and conveniently effected and all seams avoided. The tape cover is then coated with asphaltic varnish. Special attention in this form of insulation should be given to the insulation of the field terminals projecting from the surface of the core, as moisture finds an entrance to the field coil more readily at these points. To provide against this contingency, the wire leading from these terminals is well taped before the field coil is insulated; the tape is drawn up close as possible to the terminals. Finally these vulnerable points are carefully varnished and painted, and in certain types of motors the field coils are enclosed in sheet copper for greater security.

The testing of the insulation of field coils is an important feature in their construction, and this is especially true where new or untried materials are used for insulation. It should be determined beyond any doubt that all materials used for insulating coils will withstand the varying degrees of temperature to which they are likely to be subjected in the course of operation. Often in practice a motor is subjected to overload or improper handling and a consequent rise of temperature.

For method of insulation above referred to the following tests have been attended with good results:

1. The field coil should stand, without impairing its insulation, a difference of 2,000 volts, between the field winding and the pole piece, or the field winding and its spool, when the coil is placed on the pole piece.
2. A perfectly insulated field coil may be submerged in water for twelve hours without the insulation dropping below 400,000 ohms.
3. The field spool may be kept at 140° Fahr. for eight hours and the insulating resistance of the coil maintained after cooling.

To numerous causes are traceable the troubles of street railway armatures. External troubles are due principally to oil and water, and internal troubles to short circuits, open coils, grounding of commutator, crosses and grounds. The break-downs are caused by the rubbing of the armature body on the field, or by heating or flashing at the brushes.

Several reliable methods are employed to restore the insulating qualities of armatures where the vitality of the insulation has been impaired or destroyed by carbonization resulting from heating. The following method has proved to be very efficient: The armature is baked at a temperature of 120° Fahr. for several hours and when dry and still warm is painted with thin air-drying asphalt compound paint, or a standard varnish. The compounds preferable in each instance depends upon the special insulation used for the armature body and coils; these compounds having been determined by experiment upon the different insulations. For instance, varnish or shellac are preferable when mica and cloth are used for insulation; but with paper or cellulose insulation the best results may be had by the use of asphaltic varnish.

One manner of drying out an armature is to pass a current through it, but this method has been found to give bad results in many instances where there have been leaks or moisture in the armature. Internal electrolysis will invariably follow when a current is passed through an armature which has not been thoroughly dried out, and the vitality of the insulation consequently impaired. When the armature is varnished with shellac it is heated to a temperature not to exceed 90° Fahr. and treated several times with the compound; but under no circumstances should the shellac be mixed with wood alcohol or wood naphtha. After the final coating of varnish has been applied the armature is subjected to a temperature of 150° Fahr. in an oven for several hours and the maximum temperature should be attained gradually, exercising care during the process of baking to turn the armature at intervals, in order to thoroughly dry out any free fluid or moisture remaining in it. In this treatment the splices are not removed, but the heads or any covering over the winding should be taken off.

It is absolutely essential in this treatment that the armature be heated, as the insulating compounds penetrate throughout the entire insulation when the armature is treated hot and then allowed to cool; whereas should the treatment be applied to a cold armature, the effect will only be upon the surface.

A carbonized insulator will break up as a partial conductor if impregnated with insulating compounds.

Sufficient arcing to burn through the heading of the armature results from flashing of the brushes due to short-circuited rheostats or to short, weak or broken brush spring. For additional protection from this character of trouble, the head of the armature may, to good advantage, be covered with a layer of asbestos paper between two layers of canvas. Serious damage threatens the armature where flashing across from the brush to the winding occurs, causing the motor to buck and also the breaking down of fields. Only the most careful inspection of brushes will insure immunity from these breakdowns caused by flashing, and the saving of expense in motor repairs makes this inspection a paramount necessity.

In certain types of motors the armature bearing is too small, and not properly proportioned. Constant vigilance must be exercised to maintain proper alignment in these armatures the position for which should be half-way between poles pieces, otherwise, should there be any looseness in the bearing the direction of the car will throw it against the rotation of the pinion as the stronger magnet will draw the armature towards that pole piece.

Carbon dust on the commutator bead ring or carbonized oil on the surface of commutator will cause flashings. A material of which some commutator bead rings are composed, and which, offering a low resistance, forms a partial conductor should not be allowed to come in direct contact with commutator bars. This style of ring carbonizes when an arc passes over its surface and to avoid flashings the commutator bars should be covered with strips of mica before the ring is used.

Sometimes a ground is caused by carbon dust and oil leaking over the surface of the commutator ring, and in this case, where the armature will test low to ground, the ring should be cleansed of the disturbing matter.

Sometimes a ground will occur on an armature, when to cease operations, would cause serious inconvenience. In such emergency the motor can be operated providing not more than three coils are burnt out. This is effected by cutting out the burnt coils and plugging the commutator bars together, i. e. soldering the ears together or a jumper may be inserted or a brass plug driven in a hole drilled between the bars. When one end of a coil is cut out from a commutator bar, the other end must be cut also where it connects to the symmetrically located commutator bar. An armature thus prepared to meet an emergency should only be operated as long as absolutely necessary, as this armature, being forced to carry more than its share of the load when working in parallel with another motor, will become overheated resulting in the destruction of the insulation in a short time.

Great care should be exercised in repairing armature coils, not to drop a particle of solder so that it will short circuit two adjoining commutator segments. This would result in the burning out of the armature coil when the motor is started and is due to the counter E. M. F. developed in the coil, sending strong currents through it and overcoming its lesser resistance. In like manner the destruction of the coil will be wrought should the terminals of two coils in series be connected to the same commutator segment.

INSTRUCTIONS AND HINTS TO INSPECTORS.

MOTORS.

At least once a week the commutator cover and inspection plates should be removed, and the nozzle of the air hose passed around the commutator so as to blow the accumulation of carbon dust and dirt through the lower inspection plates. See that there is no moisture in the air hose before performing this operation. Examine brush holder shunts to ascertain if they are connected and in good order. The brush holders, yokes and insulators should be carefully scrutinized to see that they are in proper working order, and look to the proper alignment of the brush holders with the commutator. Between the commutator and brush holder there should be about 1/8 inch of space. Remove for readjustment or renewal, brushes and brush holder pressure arms that are not in good order. When a brush is worn away within 1/4 inch of the limit of the pressure arm action it should be renewed. The brush holder spring should be at all times maintained at normal tension, having not less than 6½ lbs. per sq. in. of brush cross section on each pressure arm. The holders should be readjusted if the variation in any motor from 6½ lbs. exceeds ½ lb: per sq. in. Keep all parts, especially brush-holder yokes, and brush holder insulators free from carbon dust. Examine brush leads at the brush holders for loose connections. Sometimes small parts in the motor such as screws, bolts, etc., become loose and may work down between the armature and pole pieces unless the inspection is rigorous and the trouble forestalled by tightening these loose parts before they work out of position. When string bands show evidence of carbonization they should be wiped with gasoline and lightly coated with insulating varnish. A commutator in good order will show a smooth, polished surface of a deep bronze color. If it shows pronounced flat or rough spots, or if the mica is burned at the end of commutator, or between the segments, removal for repairs is imperative. If, however, the flat spots are slight the trouble may be remedied without removal by the application of the sand paper block or the smoothing stone. All field connections should be tight, and the insulation examined for burnt spots. Examine for loose armature bends which may be in contact with motor frame or pole pieces. See that the clearance between the pole pieces and the armature is normal.

To safeguard the motor from undue end thrust the axle collar should be tight upon the axle, and properly adjusted. All loose gear, and gear case bolts, and bolts about the motor should be tight and in good condition, and particular attention should be given to the armature and motor axle cap bolts. For undue wearing examine motor axle bearings, and also gear and pinion, which should be tight, well lubricated and not over-worn.

Ordinarily an intelligent understanding, and a close observance of the commutator will enable the inspector to discover many troubles without giving the motor an exhaustive test; but if the brushes and brush holders are found, upon examination, to be in good order and the trouble cannot be otherwise traced, and the commutator presents an abnormal appearance, then the motor will have to undergo a complete test to detect the trouble.

The commutator is an almost infallible indicator of motor troubles, being the weakest part of the machine, and any defects of fields, brushes, brush holders or armature coils are almost sure to show upon it, and the presence of the trouble may be noted in the failure of the commutator to maintain its normal bronze-dark, smooth and polished surface. Field troubles are indicated by arcing on brush holders and open circuits by arcing at the end of the commutator.

MOTOR RHEOSTATS.

All accumulations of dirt should be blown out from around the grids at least once a week, and the grids examined for open circuits by passing the fingers over the lower end of the grids. If there is an open circuit it will be indicated by unusual vibration. See that all bolts and nuts holding grids to the car body are firmly in position and that all wires and connections are in good order and properly connected. Any foreign substance, such as dirt, stones, nuts, bolts, etc., lodged between the grid and frame or on top of grids, or burnt and warped grids coming in contact with one another are the causes of short circuits and should be guarded against by careful inspection. Arcing will occur in parts of the frame, and rods if the mica insulation tubes are burnt through, and some efficient means should be employed to protect these parts from dirt and water. Car bodies may be protected from damage by fire by introducing between bottom of car body and top of resistance some fire-proof material of very low heat-conducting properties, such as asbestos sheets.

TYPE M CONTROLLERS (G. E.).

To secure good contact, examine and try tension of master control fingers and polishing cylinder and fingers. All accumulations of dirt, or carbon dust should be scraped or wiped from arc deflector division plates, and from inside of cover. Look at the adjustment of each finger of controller to insure perfect contact, and see that all connections are firm and in good order. The auxiliary fingers should be kept polished and the contact always perfect. Proper contact may be determined by pressing down the button on the controller handle. The cylinder and fingers should be kept lightly lubricated with vaseline, and the shaft bearings of reverse switch and cylinder oiled slightly, care being exercised to remove all superfluous lubricant. The controller should be blown out with the air hose, using care that no moisture is in the hose. The reverser should be tried, after the inspection is completed, by throwing it several times, and contactors should be tried to see if they pick up properly.

TYPE M. CONTACTORS AND REVERSERS (G. E.).

The bottom tip of contactor fingers should travel on the top tip not less than 1/8 in. and when the wipe is less than that, the tip is over-worn and needs renewing. By pressing up under contactor fingers these defects may be observed. All screws, bolts, and connections should be examined to see that they are tight and in standard order. The tips of interlock fingers should be kept polished, and the interlocks should be in the right position to insure proper contact. When controller is shut off the contactors should lift sharply and drop freely on each point, and all shunts should be whole, and in such condition as to maintain full carrying capacity, otherwise hinge pins are liable to burn out. By means of a long screwdriver, which can be turned with a wrench at the bottom, nearly all loose screws, bolts, etc., may be tightened. The contactors and box may be cleaned by blowing them out with the air hose.

The reverser finger and connections should be examined to see that the screws are firmly in position, and the fingers and contacts should be brightened with a few rasps of a file to secure good contact surface. Each finger should make perfect contact with reverser segments. When a finger has been softened by heat, which may be ascertained by trying the tension, it should be renewed. To see that the fingers work freely, throw the rocker several times by hand and test the strength and promptness of the reverser by throwing it electrically several times to see if there is any rebound or undue arcing. Where a segment block indicates shortening across between segments, replace it with a clean and well varnished block and keep the blocks at all times well wiped off. Test the contact of reverser finger by introducing a strip of paper between the finger and the contact and observe the way the paper pulls. Poor contact may also be detected by tapping the finger with any light tool or object. No superfluous lubricating material should be left on segments and bearing portions of fingers, and the vaseline—which is the best lubricant for these parts—should be applied very sparingly. The contact pieces for the small fingers in the master controller circuit may be kept bright and clean by doubling up a strip of emery cloth so that the emery side is exposed on both top and bottom, and passing the strip between the contact pieces. Apply oil lightly to all bearings, and after ascertaining that there is no moisture in hose, use it to blow out the reverser.

TROLLEYS.

The outer rims of the wheel should not be chipped, bent or worn away too much, and there should be no over-wear in the bushing or spindles. Perfect contact should be maintained between harp and hub of wheel by springs and washers sufficiently tight, but not so much so as to permit wheel to slide on the wire.

The spindle in the harp should be sufficiently tight to form a perfect contact, which will not be possible if the spindle holes are over-worn, and if the rivets holding the harp are not tight it will become loose on the pole. In good working order the pole should hold the wheel in exact alignment with the wire. When the alignment is not right, it should be made so by loosening the clamp bolts and bringing the wheel into alignment. This may be done with a pipe wrench while the wheel is on the wire. The pole should be perfectly straight and free from cracks and other defects and the base bolt, clamp bolt and nuts should be firmly in position. Pull the pole down to the roof of the car and note if the tension of springs is sufficient to allow proper space between the coils for compression. Where there are more than one spring to a base the tension on both sides should be equal. The pressure of the wheel against the wire ranges from 20 to 25 lbs. in city speed and 35 to 40 lbs. in high speed. The spring tension should be regulated to give the different pressures required. The tension of the springs and the pressure exerted against the wire may be very easily determined by the simple expedient of testing the lifting capacity of the pole. This may be done by suspending a hook scale from the rope at the end of the pole and hanging any convenient weight upon it. Whatever weight the pole will lift above a trolley wire of standard height is equal to the pressure of the wheel on the wire. An observing inspector, after making this test a few times, will be able, with approximate accuracy, to estimate the lifting power of the pole without the use of the scales.

When a trolley rope becomes over-worn or has been broken and knotted it should be renewed, and the rope should at all times have a firm fastening with the harp. It should work freely when resetting and be of sufficient length not to pull the trolley from the wire at railroad crossing and other places over standard height. By tripping the retriever to ascertain if the spring tension is greater than necessary to operate the retriever properly, damage to the hood or roof is avoided. If the tension is excessive the rope may be broken or the trolley pulled down with undue force. The trolley board should be examined to see that it is securely fastened to the car roof. Care should be exercised when lubricating trolley wheels and bases to not allow the lubricant to drip on the roof, and after these parts are lubricated all superfluous oil should be wiped off. To ascertain when the bases need lubricating the pole should be swung from side to side below the wire and no oil should be used so long as the base works freely.

In interurban service an extra pole equipped for immediate use in case of emergency, together with the following miscellaneous equipment, should be carried:

One extra retriever equipped with rope; one headlight in place for signal; one fire extinguisher; extra supply of air pump and light fuses, together with car and control fuses where used; two trolley pick-ups; coupling link and pin; one coupler or pulling bar; classification and marker lamps, where oil lamps are used; telephone; three sets of white, red and green flags; fusees and torpedoes; suitable and sufficient tools for changing trolley pole and making light repairs. In addition, each member of the crew should be provided with white, and red lanterns in good working order.

Too great care cannot be exercised in the inspection of brake equipment, and the inspector should know, to a positive certainty, that it is in safe working order before the car is permitted to start out on its run. The air pump should be tested to its greatest capacity; the brake valve handle in release position, and for automatic air, 20 lbs. difference between train line and auxiliary should be registered on the gage. If the gage hands do not show the 20 lbs. difference, reset the governor. The brake should be applied to show a reduction of 40 lbs.; set brake-valve handle at lap position; examine air gage to see if its operation is good. Look, while brake is set, for leaks that may have occurred in cylinders, triple valves, reservoirs, pipes or around brake valves, and pipes leading to them. Where leaks are present the brakes will not remain firmly set while brake-valve handle is in lap position. Look to the brake cylinder piston, and if it travels more than 5 inches adjust the brakes. When release springs are acting normally the brakes will be entirely free when released, otherwise they will bind the wheels. Brake shoes that are over-worn or broken should be renewed at once, and adjusted in proper alignment with the wheels and the shoes on opposite wheels should be kept corresponding at all times, with reference to wear or thickness. Brake-shoe keys; shoe heads, pins, cotter pins, bolts, nuts, etc., should be examined to see that none is missing, loose or broken, and brake beams should be inspected for warps, breaks or cracks, and for over-worn, or missing bolts, pins, cotter pins and nuts. Hangers and pins connecting brake-shoe head and beam to truck should be examined for over-wear, and to prevent grabbing, and chattering by the brake when these parts are not in good and firm condition. It is important that the entire brake rigging be closely inspected, and particular attention given to maintaining the cotter pins in perfect condition, likewise that all adjusting jams and nuts, and the threads of turnbuckles are in good order.

All pull rods should be free from cracks and flaws, and the rods, levers and slides kept well lubricated. See that rod, pins, hand brake, brake staff and chain are not over-worn and in good general condition. All reservoirs should be drained every day.

A slack adjuster should (if used) be placed at its lowest range of movement before adjusting brakes. To operate properly it should not travel to a maximum position, leaving the correct piston travel.

CONTROLLERS.

HOW TO OPERATE CONTROLLERS WITH ECONOMY.

The operation of controllers is not in itself a very complicated duty. Any operative of ordinary intelligence can soon master the necessary details of manipulation sufficiently well to run a car, but the qualities which distinguish the mere mechanical operator from the one who combines care and good judgment in the performance of the duty, are those which insure to the company the largest measure of economy in operation, both by a saving of power, wear and tear on equipment, and prevention of expensive accidents. All of the series-parallel controllers which are in common use today have reverse levers at the right of the stand, or on top, and nearly all of the controller handles move around in the direction of a watch to turn on current and in the contrary direction to turn off current.

Proceed now as follows:

The brakes should be off before starting a car, and the controller handle at the opposite end of the car should be in the "off" position and canopy switches closed.

1. Move the controller handle to the first notch and if everything is right the car will start.
2. After the car is well under way move to the second notch and then on to the last notch, driving the handle from notch to notch without stopping between notches.
3. When on a notch hold the handle there until the

car has attained the proper speed, and then move on to the next. This saves current, prevents slipping of wheels and straining of motors.

4. When reaching the notch where the motors are in series and no rheostat resistance is in circuit, do not move to higher notches where motors are in parallel until they have gained nearly maximum speed in the series position. This saves power. The motors exert the greatest pull on this series point and should be used on steep grades. A long mark on top of the controller indicates the notch where motors are in series without rheostat resistance.

5. On the K-10 controller use the 5th running point for slow running and the 9th for high speed, and do not use either the 5th or 9th points on grades, as the waste of current and strain on the motors are considerable. The running points on the top of controller may be distinguished from the others by longer or heavier marks, and the motors may be operated on these points indefinitely without wasting current in rheostats or overheating. At the 5th point the motors are in series and resistance all cut out.

6. Do not stop at any point when shutting off current, but turn the handle briskly to the off position from wherever it may happen to be.

7. When at a standstill the car is moved backward by pulling back the reverse lever and turning on the current.

8. Never reverse while running unless to avoid serious accident. When necessary, however, in an emergency, to make a quick stop, throw the controller handle to "off," pull the reverse handle back and then move controller handle to first notch. This is an alternative re-

sorted to from necessity at times, but is by no means always effective or satisfactory in results, as there is danger of blowing out a fuse, thereby shutting off the power, and serious damage to a motor may ensue. With a series-parallel controller, however, there is one expedient which may be resorted to in order to make a sudden stop while running and when the power is cut off and brakes will not work. This is accomplished by converting the motors into generators of current, and that effect is produced by reversing if the car is running forward, or by throwing the reverse lever "ahead" if the car is running backward, and turning the controller handle to the highest point on controller.

If a car is run with good judgment and not permitted to get beyond control, this method will not have to be resorted to, except in case of the failure of brakes.

THE G. E. B-8 CONTROLLER SIMPLIFIED.

The wiring of the G. E. B-8 controller may be simplified, and the size reduced without impairment of value by eliminating the electric braking features, and under certain conditions with advantage to some roads. Where cars are equipped with both air and hand brakes, the removal of the electric braking feature is more than balanced by a decrease in the width of the controller cylinder from 31 in. to 19½ in., thus giving more vestibule room and reducing the load on the sub-sills.

The change was made by taking out the stand wiring, fingerboards and cylinders, and then the cut-out switch box on the bottom was cut to measure 14½ in. and the back of the controller shell was placed in a planer to be cut off to the desired size. (Figs. 1 and 2.)

By cutting out a piece between the reverse and braking handles, the controller cover was also reduced in width and without any new castings whatever, and the side and back were made to fit as shown in Figs. 1 and 2. In the transformer controller the running and reverse cylinders are in their original state, but owing to the change in the cut-out switch box, the last two blades to the right are removed to give the switch cut-out six knife blades instead of eight.

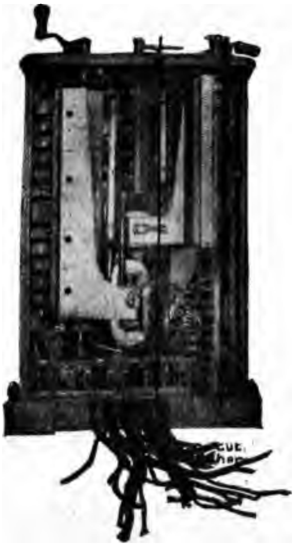


Fig. 1. Simplified Controller.

A piece of fiber fastens all wires which are led to the right side.

EQUIPMENT.

Magnetic Fuse Box.—The Westinghouse Electric Company has recently developed a simple type of fuse, Fig. 3, which has been introduced by a number of roads in addition to the standard circuit breaker.

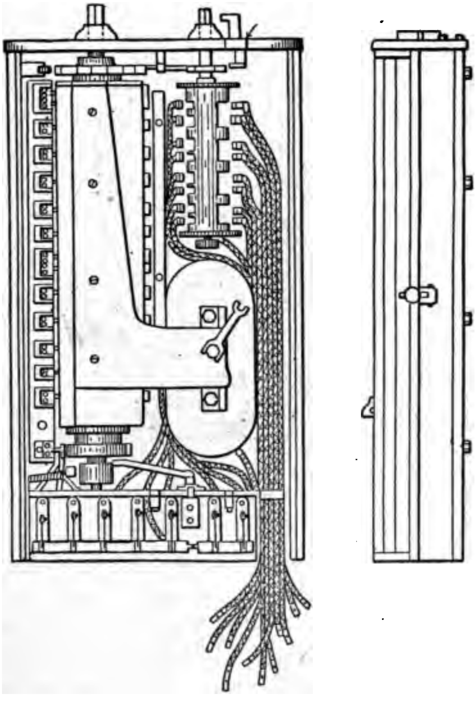


Fig. 2. G. E. B-8 Controller Braking Cylinder.

Circuit breakers materially reduced the expense for fuses, and were therefore looked on with favor when first installed on street cars. It has, however, become a frequent occurrence to overload the motor and trip the breaker, as it is very easy for a motorman to throw in the handle of the circuit breaker. This, however, is unnecessary and causes an excessive flow of current when the circuit is broken suddenly, and produces heavy strains on the motor windings; it also causes a fright to passengers. This new device is a magnetic blow-out form of fuse which overcomes the objections to the use of the old fuse box. This circuit breaker has an all-metal case with the live parts entirely enclosed, similar to those used on street cars. A short copper strip carries the current down from the terminals, which passes through an arc chute, supported inside of laminated punchings, thus giving an efficient magnetic blow-out. The blow-out is produced by the ribbon itself, and a single turn of the ribbon through the iron circuit provides magnetism enough to blow out the arc formed when the ribbon

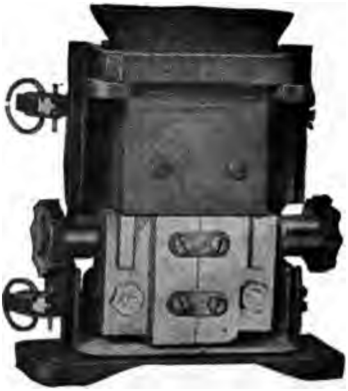


Fig. 3. Magnetic Fuse Box.

melts. The fuse box is very compact, as is shown in Fig. 3. New fuses can be readily inserted without opening the case or using any tools, simply by turning the insulating handles on each side of the box.

The sheet iron front of the box may be easily removed in case any repairs are necessary. The arc chute is a single piece and may be readily and cheaply replaced.

It has been determined by careful observation that over 42 per cent of motor commutator, and brush holder troubles owe their origin to fast feeding of controllers. To these troubles are largely due the introduction of automatic devices for limiting to a fixed maximum the amount of current received by the motors.

The injurious effect upon motors when allowed to take an excessive amount of current during acceleration has been established beyond debatable ground, and the damage is not only confined to the commutator and brushes unprovided with commutating poles, but the gears and pinions suffer from the impact of the heavy blows which they receive. It has been demonstrated that time limited devices which have been introduced to some extent with K type controllers to effect the result in a different manner, i. e., by delaying the movement of the controller cylinder, has only met with indifferent success.

With an ordinary street car any rate of acceleration may be expected to a point terminating with the slipping of the wheels. For a short period, with track in most favorable condition and with total weight on the driving wheels, a rate of three miles per hour per second may be attained, but with unpleasant effect upon passengers unless attained by very skilful and gradual manipulation. Under normal conditions the use of the automatic control will give a maximum acceleration of about 1½ miles per hour per second. Hence, concisely stated, the paramount desideratum is to have the current set so that under the varied conditions of load, grade and track adhesion, an average acceleration may be obtained, thereby relieving the motors of undue strain, while securing efficient acceleration.

The variables, however, under some conditions oppose obstacles to uniformly satisfactory acceleration, as it is not possible to set the current limit relay of the plain automatic control to provide against all the varying conditions of operation, as, for example, if the relay is set for an amount of current sufficient to obtain the proper rate of acceleration for an empty car on a level stretch of track, the same amount would fall short or prove insufficient to start a heavily loaded car on a heavy grade or a sharp curve.

These difficulties have, however, been met by: **1st.** The employment of a switch which shunts the current limit relay and causes the control to take additional steps regardless of the current. 2d. The use of two current relays having different settings, and which may be used in connection with a master controller provided with extra positions, in which the current limit of higher setting will be cut into circuit, or a separate switch accomplishing the same end.

The car or train will be normally accelerated by either of these two methods, the relay having the low current setting, but the second relay may have to be put in with a heavy load on grades or curves.

Current limit relays with dashpots for the object of producing a definite time lag have been designated to overcome the obstacles of a single current setting. The current limit relay will come into action, and not permit a superfluous amount of current being taken, so that if a car is heavily laden, or if the motors are required to take a heavier current to accelerate the speed of car, it will be prevented from taking an abnormal amount of current away by the limit relay coming into action.

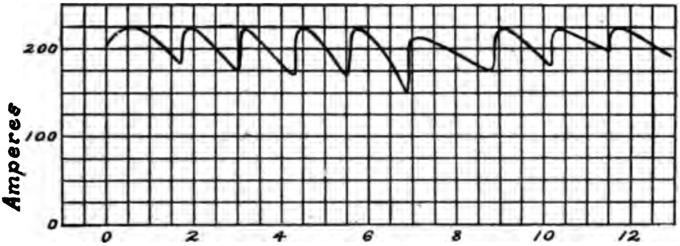


Fig. 4. Automatic Control—Current Record of Light Car Starting on Level.

Fig. 4 shows, starting on a level track, the record of the typical current of a lightly loaded car, furnished with four 75 h. p. motors. The notches were obtained by a slight time element in the dashpot of the relay, and the current secured was below the setting of the current limit relay.

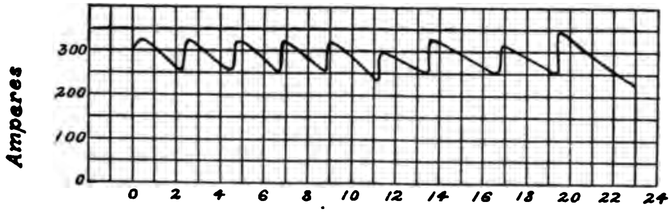


Fig. 5. Automatic Control—Current Record of Heavy Car Starting on Grade.

Fig. 5 shows the record of a loaded car, while accelerating on a grade. In this case the maximum current was prevented from exceeding a fair and safe amount for the motors by the limit relay coming into action.

There are two groups of motors in this four-motor equipment, a permanent parallel connection being made in each motor, and in making the series parallel connections each group is treated as a single motor.

It will be noticed that in passing from series to parallel, full torque is exerted, and throughout the range of acceleration a practically uniform current is kept. There must be some method of compensation for the fixed current value of the limit relay, and considerable thought is required as referred to acceleration with definite maximum current, otherwise the acceleration will be too violent under conditions of lightest loads or the wheels will slip, and it will be impossible for the motors to start the car with a heavy load on a grade.

CONTROLLERS OR REPAIRS.

Double Controllers.—This controller takes the place or preferably serves the same purpose as four-motor capacity controllers, and may be constructed by backing two old motor controllers in pairs and turning their cylinders as one by the use of an intermediate idler, which meshes a gear on each cylinder. This transformation has been successfully made with controllers of the type K-2, K-10 and K-11, in connection with four 50 h.p. motor equipments, and can be made with any controllers of D form. These controllers are fastened back to back on the car platform with or without intermediate insulating filler, as the occasion may require. The tops of the controllers are removed and a new cover, which contains the mechanism for the two-fold control, takes their place. This mechanism consists of a plate and three gears mounted as is shown in Fig. 6.

The intermediate gear acts as an idler, while the other two gears are attached to the controller spindles. Consequently by attaching the regular controller handle to either one of the cylinders it is possible to turn the other at the same time.

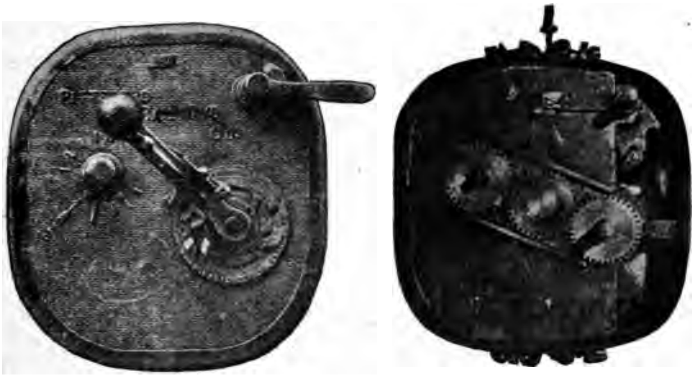


Fig. 6. Top of Double Controller with and without Cover.

In case of trouble one controller may be operated independently of the other, as the idler gear is removable, and any combination of motors is possible. Fig. 6 shows that reversing is effected with one of the original handles, quick action being secured by the underplate levers connecting the reversing cylinders.

The Fuse.—A device whose function in a circuit is of great importance in railway motor operation is the fuse, as it protects the motor from excessive flow of current and the attending injurious results. The fuse may be said to be the guardian of the equipment, as the current before passing through the motors passes through the fuse. Many types of fuses are in general use in electric railway operation, besides other devices designed for the same purpose, such as automatic circuit breakers. The fuse in its simplest form is made a soft wire composed of lead with an alloy of some kind which will not withstand a temperature above that which a predetermined volume of current will cause. When the current becomes greater than the capacity of the fuse to resist the temperature, it melts and opens the circuit, which prevents the burning of the armature or field coils. If through some untoward happening in the electric equipment of the car an excess of current were fed to the motors, damage by excessive heat in the armature and field coils would result, but for the interposition of the fuse. The fuse, which is a short piece of lead with alloy or a very fine copper wire, is arranged between two binding posts, thus breaking the continuity of the wire through which the current flows, and offering to the heat developed by excessive current a lower melting point than that of the wire. Wires themselves become heated when too much current is permitted to flow through them, and when the temperature of the conducting wire reaches that degree of temperature which threatens the safety of the armature, and field coils the fuse melts and prevents the damage or destruction of coil insulation. In the use of copper wire for fuses, the wire should be very much finer than the conducting wire between which it is introduced in order that by reason of its reduced size it will melt at a temperature which the stouter wire would withstand. Covered fuses as shown in Figs. 7 and 8 are more generally used at the present time than the lead or bare fine wire fuses, as the former have advantages which have made their employment preferable to that of the more primitive types. The covered fuses are not accompanied by the flashing and loud report which are undesirable features of the bare fuses when they blow out. The covered fuse is in the form of a fusible conductor enclosed in a tube and surrounded by a filling, which prevents arcing and flashing with short circuits, and the heat from them is not permitted to damage or disfigure the paint and woodwork of the car contiguous to them. With the earlier types of fuses the insertion of them requires the manipulation of thumbscrews, which at times is quite an onerous undertaking, whereas the covered fuses are quickly and easily adjusted by means of clamping springs, which consume but little time and present no difficulties in bad weather,

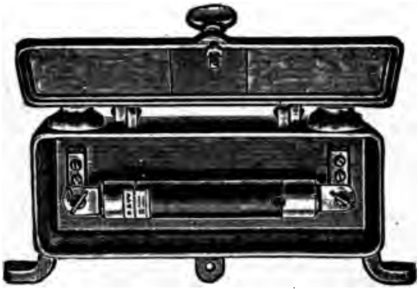


Fig. 7. Closed Fuse.

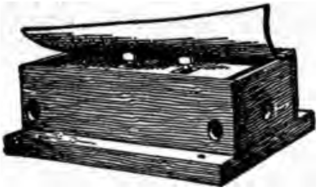


Fig. 8. Closed Fuse.

Emergency Brake.—This brake, Fig. 9, recently perfected in England, combines all the best known mechanical principles of braking effort and should be thoroughly studied. An iron or steel shoe is the operative part and its base is shaped to engage the rail head, and its top provided with a flange and inclined groove to engage the car wheel. A slotted link under pressure from a compression spring holds each shoe close, so that when free the shoe drops into the rail groove, while the flange mounts the shoe, thereby converting the weight on the wheel into braking effort. A wire cable connected to a platform lever holds the shoe from the rail and is put on by pressing another lever, which frees the shoes, lifting a detent out of the first lever.

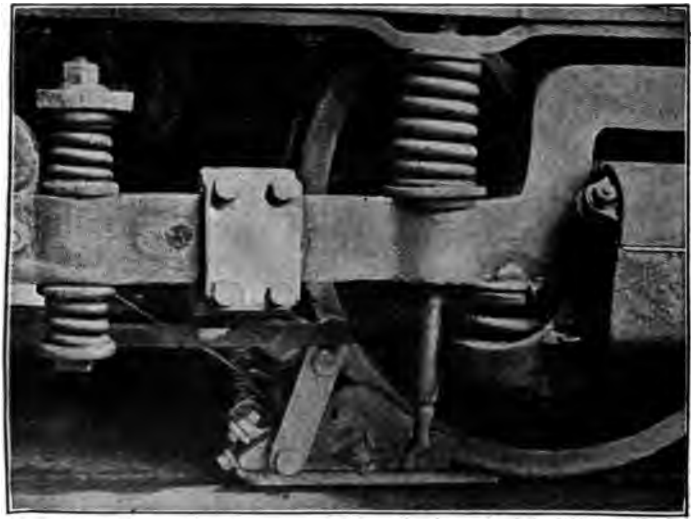


Fig. 9. Emergency Brake.

At present they are arranged on a single truck car, only the two rear wheels are braked, but the operating platform lever, Fig. 10, has two knobs, the front being marked "forward," and the back one "backward braking," so that in a backward run the motorman breaks the wheels which normally would be in front. The arrangement of these levers is shown in Fig. 9.

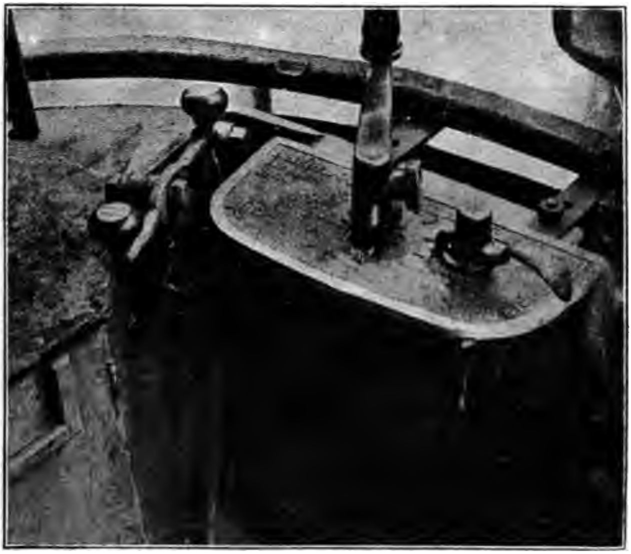


Fig. 10. Emergency Brake Controller.

The Emergency Straight Air Brake of the G. E. system, provided with differential governors, is shown in Fig. 11.

The compressors are of type CP-22. The function of these differential governors is to equalize the work on all the pumps on a train of cars when operating in multi-

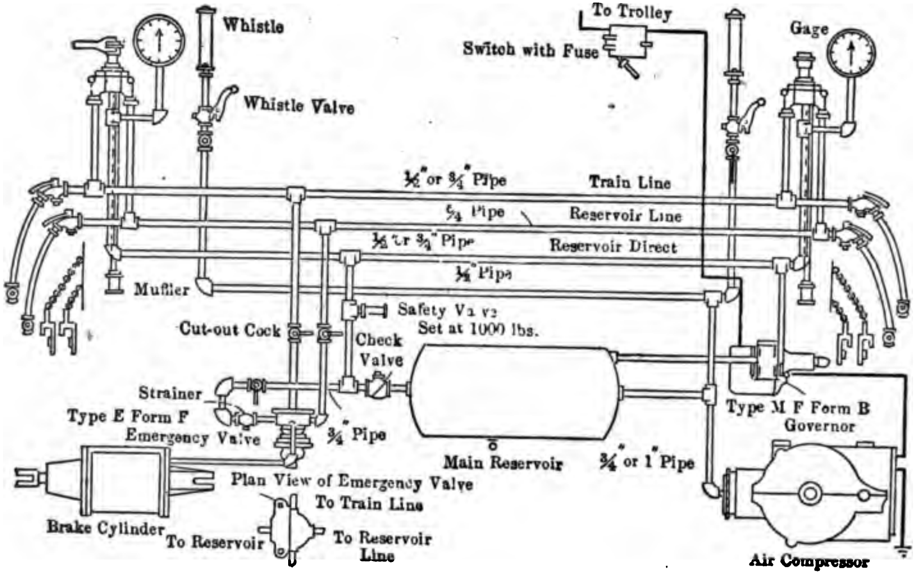


Fig. 11. Connections of Emergency Straight Air Brake System for Multiple Unit Operation.

ple unit connection. This is accomplished by the provision of two diaphragms of an unequal area. The larger diaphragm is connected directly to the main reservoir, and the smaller connected to a pipe which is in connection (when the emergency valve is in its normal position) with the reservoir line running through the train. A check valve is located in the pipe leading from the main reservoir line to prevent the passage of air from the latter to the former.

If the governor on any car starts the compressor, the pressure in the main reservoir of that car, and also the pressure in the reservoir line running through the train is increased, but the pressure is not raised in the main reservoirs on the remaining cars. This results in the governors on the remaining cars being set in operation, and insures all the compressors doing an equal amount of work.

The connections of the emergency straight air-brake system for multiple unit operation are shown diagrammatically.

MOTOR REPAIRS.

Commutators as a general rule will not cause much trouble if they are given close attention and proper care, but are capable of creating serious difficulties, and causing great damage, even to the extent of being entirely ruined, if neglected, and the first evidences of irregularities are not rectified in the beginning. No time should be lost in promptly arresting the advance of such trouble as the eating away, or burning out of the mica between the commutator bars.

There may be assigned several causes for this trouble, but the principal one is "bucking" or flashing over. The effect of this flashing over may be noticed first at the outer end of the commutator on the corner, and makes its appearance first as a mere speck, but which grows gradually larger. Sometimes an accumulation of carbon or copper dust or other foreign matter will cause a momentary short circuit between the bars and rings of fire will appear around the bars, burning in deeper every

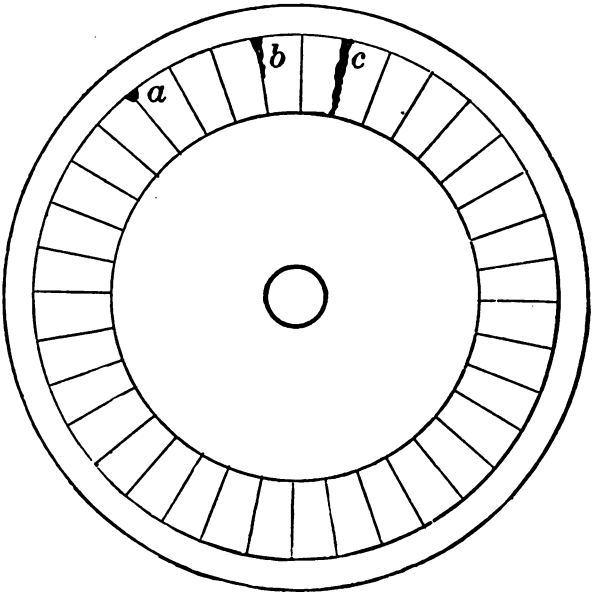


Fig. 12. Initial Defect in Commutator.

time the flashing occurs. The trouble begins with a slightly burnt spot, in the center of which will appear a small piece of charred mica. In Fig. 12 is shown the initial defect, which seems trivial, but if not arrested immediately upon detection will eat its way down to the clamping ring by successive stages, as shown by the letters *a, b, c* in Fig. 12. When the burn reaches this stage of development it is only a matter of a little time when the mica ring will become punctured, a ground established and the commutator destroyed. The dotted lines in Fig. 13 show the original form of the commutator bar and the clamping ring, between which is located the mica ring. The irregular solid line describes the burn after it has penetrated the mica ring, which is not visible in the illustration.

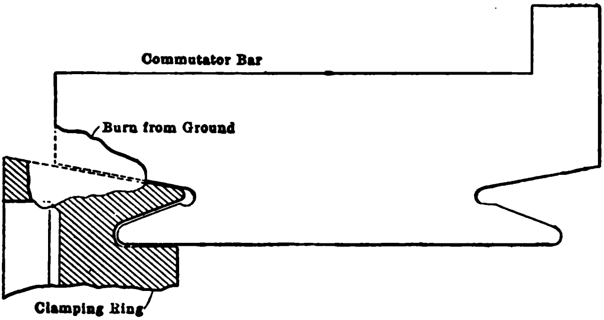


Fig. 13. Burned Commutator Bar.

When the speck at the corner shown at *a* in Fig. 12 first makes its appearance, or at any stage of the trouble before a ground appears, every particle of the charred mica should be removed with any suitable tool. Every particle of the burnt insulation should be dug out until the sound mica is reached at the bottom, and which may be known by its firm and white appearance. The place should then be filled with a solution of silicate of soda and plaster of paris—a mixture of waterglass. As this mixture becomes hard in a very short time, it should not be allowed to stand any length of time before it is applied.

If the crevice is small, pulverized glass may be used to advantage instead of plaster of paris, and when dry becomes exceedingly hard, but requires more time to set and is therefore not as available as the mixture of waterglass for large crevices, such as is shown in Fig. 13, where a ground has occurred and burned out a large space. The powdered glass filler may be used, however, when there is plenty of time to allow it to dry out thoroughly and where the hole is very large, requiring a goodly quantity of the mixture, it is better to make successive applications or build it up in layers, allowing each layer to harden well before making another, but each successive layer should be laid with a freshly made mixture, as otherwise it will harden before it can be applied. It is well always to expose the waterglass to the

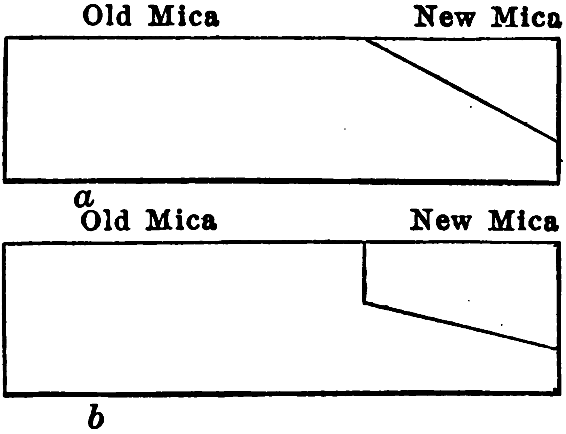


Fig. 14. Commutator Bar Repaired.

air for a time before mixing it, as this has a tendency to prevent its hardening too rapidly. One method of remedying this trouble in its early stages has been to remove the charred mica and then introduce a new piece, as shown at *a*, Fig. 14. By this method the new mica joins the old at the surface of the commutator at an angle, leaving a sharp shallow point, and the mica is made firm by calking bars on either side. As it is practically impossible to effect a firm and solid joint by this method, since the delicate feather edge will resist no usage, the bad spot soon reappears and the trouble begins again. When possible a square fit, as shown at *b*, Fig. 14, should be made; it is not often, however, that the nature of the crevice will permit of this.

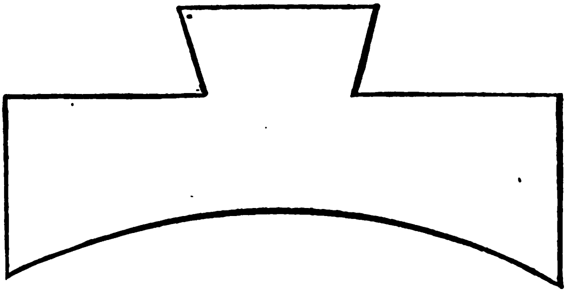


Fig. 15. Commutator Polishing Block.

Fig. 15 shows a commutator polishing block, which is used in connection with sandpaper for smoothing the commutator. Some companies use a stone hollowed out to fit the curvature of the commutator surface; but the consensus of opinion as to superior utility is in favor of the sandpaper. Emery should never be used for smoothing down the commutator, as the sharp particles of emery become embedded in the surface of commutator, and in turn grind the brushes. The eating or burning away of the mica may to some extent be reduced by rounding off the corners with a file. The sandpaper and block will go far towards maintaining the good condition of a commutator, but care and good judgment must be exercised in its application.

MOTOR LEADS, LOOSE OR GROUNDED.

Troubles from loose or grounded motor leads, followed by fire, may be provided against by a few simple precautionary measures in the shops.

The motor area on double truck cars, which may be subjected to any sweep on curves, should have the cable taps brought opposite to it, and even if the motor shell must be redrilled to accomplish it, the motor terminals should be brought out through this area, using the most flexible and best wire in the leads. The motor lead wire should be made to fit the motor lead bushing, and the bushing made to fit the hole in the shell. In drawing the lead through the bushing, soapstone or clay should be used as a lubricant instead of any oily lubricant, which causes the bushing to rot. When using ordinary sleeve connectors they should be sweated to the cable taps, and into the other end of the connectors the prepared ends of the motor lead should be brought. If special terminals are employed both cable taps and motor leads should be sweated into them and a test made by pulling.

The motor end leads should be prepared by stripping off a small bit more of the insulation than is required, so that after cutting the wire off, the rest will be full size all the way to the end.

The original "lay" of the wires should not be disturbed. After dipping them in melted solder they should be allowed to cool and then trimmed with a file. In cutting them off care should be exercised to obtain the proper length so that both current screws may have full bearing on the wire. The inner screw should be first put in tight when connecting, and this screw should be able to hold the wire by itself. It should be tested by pulling forcibly. If it stands the test it may be considered secure, and the outer connecting screw may then be tightened.

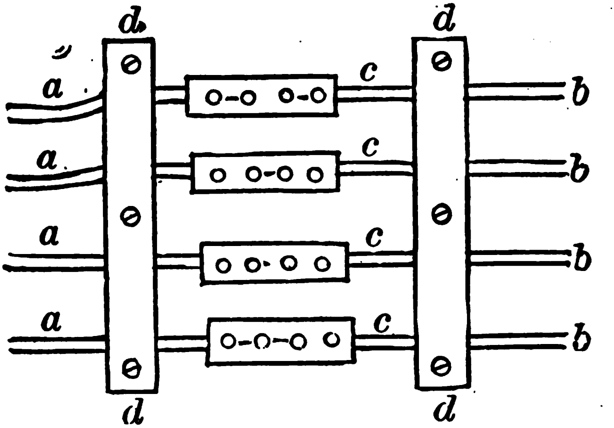


Fig. 16.

A four-hole wooden cleat should be put on both sides of the connector to avoid the working pull between the sleeve connector and the conductors engaging it. Fig. 16 illustrates the plan, the letters *a* representing the cable taps, the letters *b* the motor leads, the letters *c* the connectors and the letters *d* the wooden cleats or spreaders.

To protect the connectors short sleeves of garden hose may be used, as by this means they are readily accessible when it becomes necessary to disconnect.

SPARKING AT COMMUTATORS.

Sparking of commutators is due to a number of causes. In street-railway motors the shifting of brush holders, or the inequality in distance of the brush-holder yoke from the commutator on the two sides, or where several brushes on one arm holder being out of alignment, will cause sparking, but the most common causes of sparking in street railway motors are weak brush springs, or where the brush has become too short from wear to respond to the spring pressure. The brushes to be properly set on the commutator should be placed at a distance from one another equal to that of the total number of bars divided by the number of poles, and the bars covered by one brush subtracted from that number will give the bars of commutator between brushes. To prevent the brushes from wearing into the center of the commutator surface, where two brushes are used in the same brush holder, each brush should be provided with a separate spring, and the brushes should be separated by a dividing piece of solid material, and the wear upon the brushes should be uniform. When a commutator shows wearing away of the copper at the mica insulation it is in bad order, and requires prompt attention. When a street car motor's commutator becomes rough the brushes should be taken out, and the motor affected should be cut out entirely if the car is equipped with two motors.

As soon as a commutator shows signs of rough surface it should be smoothed and polished. This may be done by several methods. Sometimes a piece of grindstone, hollowed out to conform to the surface of the commutator, is used. While the car is being run up and down the track, the stone is held against the rotating commutator until it acquires a polish. A device, Fig. 17, fashioned from a block of wood and used in connection with sandpaper is also an efficient manner for polishing a commutator. The wood is shaped to fit the curved surface and the width of the commutator and a piece of sandpaper is spread across the concave bottom of the device, folded up at either side and lapped over the top, where it is held in position by a clamp which is forced downward by a screw handle. This device is held against the rotating commutator in the same manner as the grindstone polisher. The commutator is sometimes polished with the motor operating the car by making this polishing block shorter. Emery should never be used for the purpose of smoothing and polishing commutators, as the small particles of emery will become imbedded in the copper and wear away the brushes.

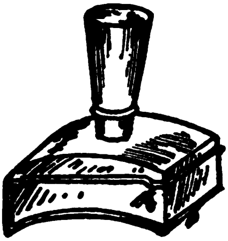


Fig. 17. Commutator Polisher.

Commutators should be closely watched and frequently examined for surface defects. When the surface is even, smooth, polished and shows a deep bronze color, the commutator is in good working order; any other surface appearance would indicate defects requiring prompt investigation and remedy. In the course of operation commutators wear out of line, develop bad flats, and high or low bars. These are defects requiring repairs by turning in a lathe on centers and demanding special care and skill in cutting in order that the concentricity of the commutator may be restored. For delicate work of this order the cut is made as light as possible, with a diamond pointed tool well lubricated when the cut is rough.

Oil and carbon dust which accumulate about the insulating ring at the end of the commutator is a cause of flashing. To prevent this a small ridge should be left around the commutator at the end adjoining the bearing, in case the brush wear does not extend to the end of commutator.

In proper condition the brushes should show a bright plumbago appearance at their contact surfaces. When they are black and scarred some trouble has been created by overheating, as will be indicated by a bluish oxide on the commutator, and the commutator will show a burnt bar below the adjacent bars if there be a short circuit between contiguous windings connected to that bar.

To prevent flashing to ground and burning through the head of the armature before the various causes for it may be discovered, it is well to head the armature under the canvas cover with several layers of asbestos paper. If a commutator bar has an open lead to it, flashing will occur when that bar passes under the brushes, and an open coil on an armature, even though this coil be connected in around the armature, will show a bad bar. The "bucking" of motors is caused by the grounding of the armature turns, which produces a short circuit between the trolley wire and the rail. This trouble necessitates the cutting out of one motor at the controller, and the car must then be run in for repairs with one motor in operation.

Soft, inferior brushes are the causes of dull, steady sparking, which results in black and dirty commutators. The burning of commutator surface is sometimes due to an increase of current flow through the motors, caused by imperfect potential delivery and accumulation of dirt on track surface. The surfaces of commutators frequently become coated with carbonized shellac which has been too freely applied in building up the commutator segments. The shellac is drawn out by the heating of the commutator and carbonizes on the surface, and this trouble continues until all the surplus shellac is exhausted. While this process is going on ridges of the exuding shellac form over the mica insulation between the bars.

When the commutator cools several bars will show these ridges. Brushes that are too soft will produce the same effect upon the surface of commutator, but upon feeling the surface small ridges of mica will be noticed between the bars. The brush may be tried with a knife blade, and if the brush is of proper hardness and the carbon comes off in small, granular pieces, the brush should not be shaved or penetrated. The same is true of a brush that is too hard. When a commutator shows a bright metal and splintered, torn surface, and copper dust is found on the inside of motor case, the brush is uniformly too hard to be used with regular brush tension; but where the brush is only hard in spots, bright rings will appear around the commutator, and a corresponding bright spot will be found on the contact surface of the brush when it is taken out and examined with a knife point, which will show these bright spots to be harder than the surrounding carbon. The same surface produced on a commutator by a hard brush will appear if the commutator is not lubricated, and this should be done sparingly, using vaseline with a small rag. If brushes squeak or are too hard, but of uniform density, they may be improved by first heating them and then dipping in hot paraffin or heavy lubricating mineral oil.

When a brush shows pitting on the side there is bad contact from a weak brush spring, and the brush receives current from the sides of the holder causing chattering and arcing between the holder sides and the brush. Arcing and wearing away of the brush may be caused by a piece being broken out of the brush where the brush spring rests.

Excessive heating of the commutator or brush caused by bad contact is indicated by the brush tapering toward the contact surface, and a brush with burnt surface indicates sparking at the commutator. The commutator contact surfaces of the brush which show a ridge down their length, on both sides of which is a commutator surface, indicate that the brush is not broad enough for the brush holder. As the position of the brush changes with the movement of the commutator, it will be worn to one surface in going in one direction and to another surface in going in the opposite direction. Phosphor bronze brush springs are less liable to become heated and lose their elasticity than other springs.

LIFTER OF BRUSH-HOLDER PRESSURE ARMS.

A number of roads have found the use of a single wide brush to a brush holder to give better results than two narrow brushes. For instance, it eliminates the ridge between brushes on commutators; the wear across the commutator is more uniform, and better performance and longer life of the brushes are insured. The disadvantage that the workman has had was the great difficulty in holding up both pressure arms and still have a free hand to lift out, and put in the wide brush. This was done by the lifter, as shown in Fig. 18. This illustration shows the shape of the lifter, especially the portion that engages in the finger rings of the pressure arms. Fig. 19 shows the lifter in place, and it can be seen that both pressure arms can be held up with this lifter with the left hand, while the right hand is free to handle the brush.

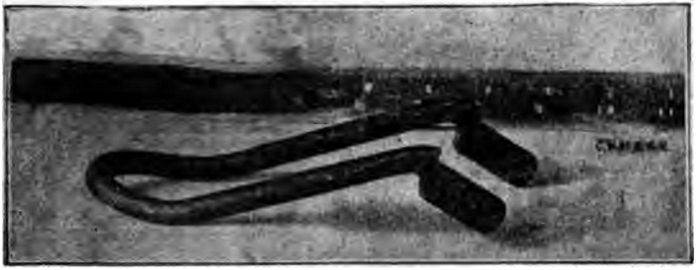


Fig. 18. Brush Lifter.

Particular attention should be given to the brushes, as numerous troubles arise from the use of inferior brushes and brushes improperly adjusted.

Recent experiments in the testing laboratories of the leading electrical manufacturing companies have resulted in procuring much definite and scientific data concerning the physical, chemical and electrical characteristics of brushes, which has been heretofore more a matter of assumption than of certainty. These experiments have enabled the manufacturers to classify the brushes and determine their respective superior suitability for motors in different branches of the railway service.

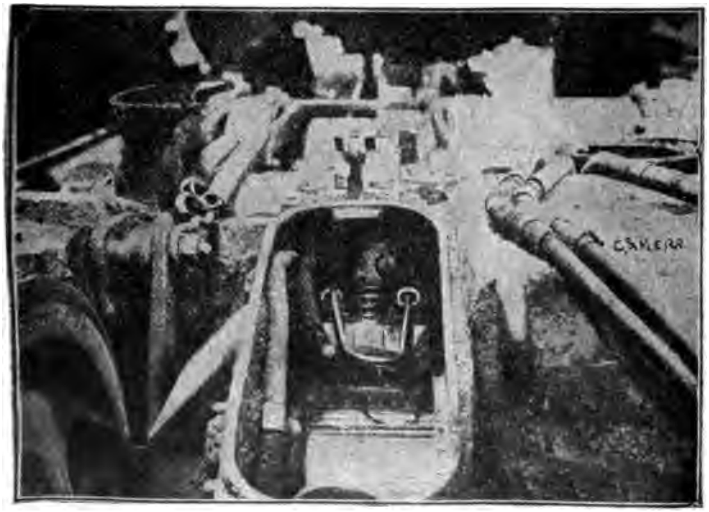


Fig. 19. Brush Lifter in Place.

These brushes now appear under three principal classifications, and a description of each class will convey a general idea of the numerous brushes regardless of the variations in minor details:

Class 1.—Styled Coke Brushes.

Class 2.—Styled Part Coke and Part Graphite Brushes.

Class 3.—Styled Graphite Brushes.

The Coke Brushes are best adapted to ungrooved commutators of railway motors of about 50 h.p. or less, operating in all service, where the abrasive and polishing quality of the brush is a prerequisite. For city service, air compressors and switching locomotives this brush, which is composed mainly of coke, is the most approved.

The Part Coke and Part Graphite Brushes are used normally with grooved commutators and are most suitable for motors of 50 to 100 h.p. in suburban and interurban service. These are medium brushes partaking of the characteristics of 1 and 2.

These brushes can work on 50 to 100 h.p. motors without the side mica being grooved, if the commutator requires only a moderate amount of abrasion to maintain its polish. This brush can be used advantageously on motors of less than 50 h.p. in slow speed service, if the commutators are grooved, as a commutator with grooved side mica requires less polishing effect.

The Graphite Brushes are employed usually on grooved commutators on motors of 100 h.p. and over. This brush is composed mainly of graphite, and possesses natural lubricating properties which tend to reduce or prevent chattering and breaking of brushes. It also has a large current capacity per square inch. This brush is suitable only for commutators with grooved side mica, as its abrasive effect is low and it does not polish the commutator and wear away the side mica. In using brushes they should be first carefully inspected to insure conformity with specifications. The thickness of the brush should not be greater than exact size or less than 0.01 in. under exact size. The width and length of the brush should not be greater than exact size, or less than 1/32 in. under exact size. The brushes should be measured by the standard box gage of exact size and not by a box gage, showing 0.01 in. under size in thickness and 1/32 in. under size in width.

There should be no copper plating of the brushes and when they break the fracture should present a uniform appearance, and show a fine grain. There should be no difference in the appearance of the texture in the two fractures when the brush is broken, both lengthwise and crosswise. A brush showing shrinkage, or stratification cracks should be condemned.

Brush Tests are made to determine the mechanical and electrical characteristics of brushes. Strength, hardness, and abrasive power are the mechanical characteristics. The maximum of current capacity which a brush possesses without producing the glow constitutes the electrical characteristic. No definite and absolutely reliable method has yet been determined to test the abrasive power by any process of easy application, although the subject is considered most important, and is at this moment engaging the attention of leading experts with every reason to expect the discovery of such tests for carbon brushes in the near future.

Experiments looking to determine the abrasive effect of many brushes now in general use has emphasized the utility of certain percentages of ash in the several classes of brushes. The analysis of this ash gives a large amount of iron oxide, Fe_2O_3 and sand SiO_2.

In order to acquire the abrasive effect necessary for efficient operation, the class 1 brushes should contain about 5 per cent of this ash; class 2 brushes 3 per cent, and class 3 brushes not to exceed 2 per cent. However, it is not just now advisable to express the abrasive effect in the percentage of the ash contained, as it is primarily the abrasive effect itself which is sought at the present time, and this may be later obtained by abrasive tests now in process of development.

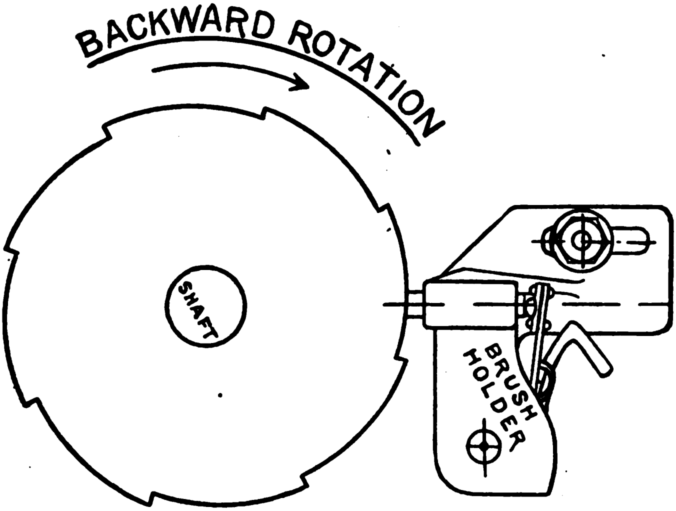


Fig. 20. Vibrator Brush Tester.

The Vibrator Test, which is wholly mechanical, determines the toughness or brittleness of the brush by a series of mechanical shocks to which the brush is subjected. Fig. 20 shows the principle of the vibrator, which consists of a ratchet wheel 9¼ inches in diameter, with eight teeth 1/16 inch each in depth, and face of wheel sufficiently broad to take the widest brush. The brush is adjusted in a standard brush holder, and allowed to bear on the wheel with a pressure of seven pounds per square inch of brush-bearing surface. The wheel may be driven by a small motor or belted from a line shaft and the speed of the wheel should be 250 r.p.m., causing the brush to receive 2,000 blows per minute, the blow consisting of a 1/16-inch fall under pressure, as each tooth passes the brush, the wheel revolving backwards. The number of revolutions of the vibrator wheel which a brush will stand before breaking will determine the mechanical quality of the brush. An inferior brush which gives poor service and breaks badly will not stand over 5,000 revolutions, whereas one which gives fairly good service will stand anywhere from 20,000 to 50,000 revolutions. A brush showing a high grade of mechanical excellence will not chip or break when subjected to the shocks of 100,000 revolutions.

A conservative estimate of what the several classes of brushes should stand without breaking is as follows:

CLASS.	REVOLUTIONS.
One	20,000
Two	30,000
Three	50,000

The Hardness Test is made by scratching the brush with pencils of varying degrees of hardness until a pencil is found which corresponds with the hardness of the brush. The Johann Faber standard "H" drawing pencils are best suited for this purpose, and this test, which is a simple and practically reliable one, is readily accessible and more conveniently applied at all times than the vibrator test, which while indicating tensile and crushing strength, is no more, if indeed it is as efficient, as the pencil test, when testing for hardness.

The Slip-ring Test is made by passing a current through the brush to a slip ring, which determines the maximum amperes that the brush can carry per square inch without glowing. The slip ring consists of a wheel of hard copper ½-inch thick and 8 inches in diameter. The face of the ring should be of sufficient breadth to test the widest brush. The current is taken from the ring by means of copper brushes in contact with the hub. A standard brush holder is used and the wheel is mounted in a manner to allow the brush to press against the slip ring, which may be driven from line shafting or a small motor and the speed of ring should be about 500 r.p.m. When the brush is once fitted it should maintain a true surface, providing the slip ring wheel runs true, and its periphery has a smooth and true surface.

It is advisable to test at least a dozen or more brushes of each quality, using a direct current, and the current should flow from the brush to the slip ring. Ordinary railway brushes may be tested with a voltage not to exceed 25. Until more exact values are determined the three classes of brushes should be required to stand the following tests:

Class 1.—100 amperes per square inch without glowing.
Class 2.—150 amperes per square inch without glowing.
Class 3.—200 amperes per square inch without glowing.

To avoid ridging in the middle of commutator and to obtain longer wear from the brush it is quite prevalent recently to use only one brush per holder, This necessitates cutting out of the bridge in the brush box, but should the brush be thrown from the commutator by reason of any irregularity, a break in the entire circuit would follow where one brush is used, and less flashing would occur where two brushes are used, especially where the commutator speed is high.

EQUIPMENT.

Trolley Poles and Bases. The electrical circuit through the car may be described as follows: The current is generated in the power station and flows through the feed wires and trolley wire and then on through the trolley wheel down the trolley pole to the trolley base. The illustration, Fig. 21, shows a modern and approved trolley base, of which there are many forms; but the principle upon which they are constructed is the same in all standard bases, the variations being merely a matter of detail. Usually the trolley wire is connected to the base, Fig. 21, and the base is provided with a socket into which the trolley pole may be placed or taken out at will. The springs with which the base is provided serve to keep the trolley pole always firmly

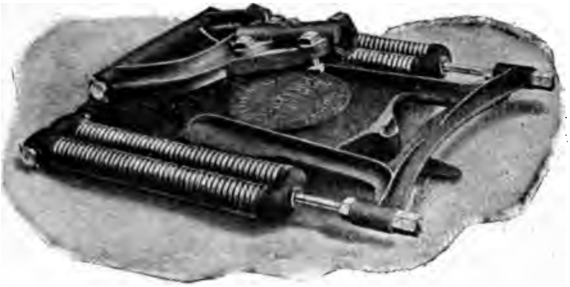


Fig. 21. Roller-Bearing Trolley Base.

pressed against the trolley wire and this constant upward force exerted by the springs is indispensable for the maintenance of the uniform pressure of the wheel against the wire; especially as the height of the wire above the roof of the car varies at certain points along the line, such as railroad crossings, where the wire is suspended above the standard height, and at bridges and tunnels where it is usually much lower.

The proper care of the trolley pole is a matter of first importance. When going over circuit breakers the power should be completely shut off and when running over crossings or around curves, the speed should be reduced and the car run with extra caution. The detachment of the trolley wheel from the wire is always accompanied by a perceptible dimunition in the speed of the car, and this indication of an irregularity should be sufficient to engage the immediate attention of a careful motorman and direct it to the cause, so that he will stop his car at once, until the trouble has been remedied by the readjustment of the pole to the wire. Points at which there are cross-overs and switches are always to be passed with more than ordinary alertness, as they are great sources of trolley pole troubles. Trolley poles get caught in frogs, sometimes causing serious troubles and delays all along the line. Sometimes a mishap of this kind will result in wrenching out the trolley stand, or will drag down the trolley wire thereby endangering the lives of the public, besides causing other damage.

The trolley wheel will invariably leave the wire if the car is run recklessly over crossings and circuit breakers or around curves.

MOTOR TRUCKS.

As an illustration of the advance in modern equipment which will engage the attention of the profession with signal advantage, the design of Curtis Truck, Fig. 22, and its construction has been introduced in this work.

The forged steel construction used throughout, and the arrangement to give easy riding qualities are the distinguishing features. No castings of any kind are employed, with the exception of center plate, brake heads, shoes and journal boxes. They have steel tired wheels; and axles carry two 75 h. p motors. Two forged steel parts separate the upper and lower wheel pieces. The lower wheel is made up of two flat bars on edge, and securely riveted to the inside pedestal jaws. The upper wheel piece is a rectangular bar extending the length of the truck and set on edge to utilize the full strength of the section. Both pedestal jaws are riveted to the upper and lower pieces and made of open hearth steel plate and bent double. The springs transmit the load from the upper wheel piece through the spring bars to the journal box. These springs also rest on spring seats cast on the journal boxes, thus relieving any vertical load from the pedestal jaws. To take up wear, both journal boxes and pedestal jaws are provided with chafing plates. By dropping the pedestal tie bolt, and taking out a turned steel bolt, at the bottom of each pedestal jaw the removal of the journal boxes is easily accomplished.

The construction of the truck end sills gives a strong corner connection, keeps the frame square and is less

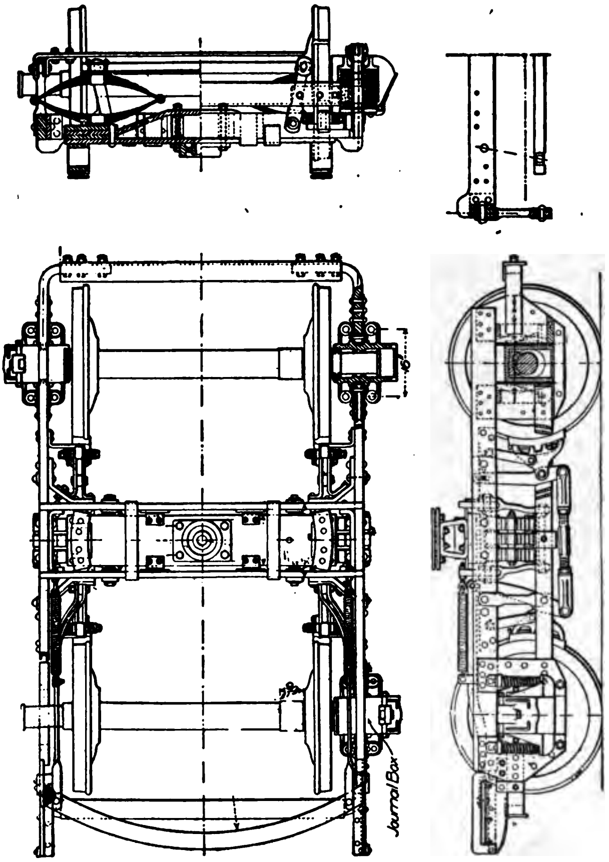


Fig. 22. Curtis Motor Truck—General Design.

liable to fracture than a sharp corner. Figs. 23 and 24 show a side and three-quarter view of the truck complete.

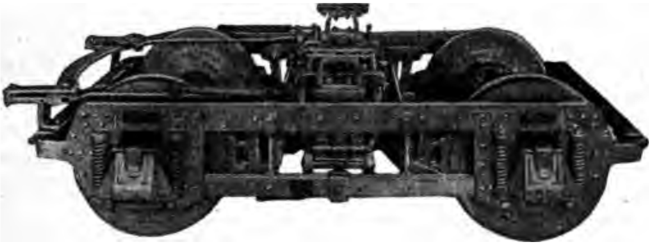


Fig. 23. Curtis Motor Truck.

The transoms are upset at each end to rest on top of the upper wheel pieces, and are steel bars set on edge. The bolster is built up of two plates with filler blocks between and rests at each end on 30″ triple elliptic springs. The bolster cannot swing sidewise and strike the wheel pieces, because the bolster is made very short.

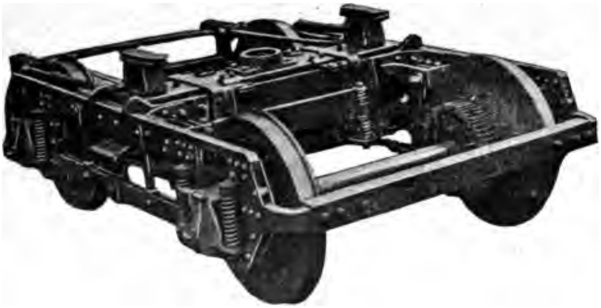


Fig. 24. Curtis Motor Truck.

All of the chafing plates are movable, and can be renewed without lifting the car body or bolster.

The motors are inside hung, with spring supported nose bars carried by brackets riveted to the transom.

These trucks are made and designed to withstand the hard usage of high speed service with the minimum amount of repairs. All parts of the truck are made accurately to templates, and are perfectly interchangeable. Fig. 25 shows motor truck complete under car on track.

Path of the Current operating a car with G. E. type K 1 controller, and two motors connected in series parallel with shunt accessory.

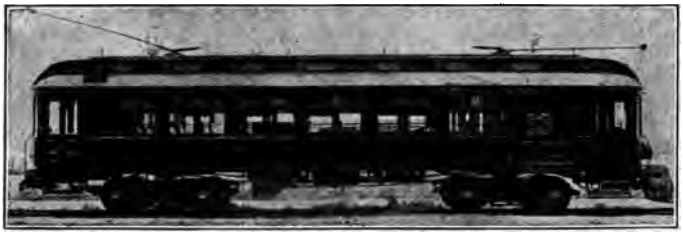


Fig. 25. Curtis Motor Truck.

Before proceeding to the path of the current at the several portions of controller handles, a few salient features connected with the operation of the controller should be well understood, and borne always in mind by motormen.

The safe running positions of a G. E. type, K or K1 controller are 3, 4, 6 and 7, and are indicated by the long, raised bars on the dial plate of the controller. The unsafe running positions are 1, 2 and 5, and are indicated by the short raised bars. The unsafe positions are rheostatic or resistance points, and the shortest of these short bars are on the multiple position of the controller, while the longer of the short bars are on the series connection position of the controller.

The circuit of number 2 motor is completely cut out when changing controller cylinder to a parallel, from a series connection and the handle of controller is midway between the fourth and fifth positions. When the two motors are placed in multiple the full connection is not made until the fifth position is reached.

Through wires marked L1, and L2, the ground ends of shunt are placed in connection with controller, and the shunt resistance employed with motors is generally tapped from the field leads on the positive side of the field circuit.

The current flows through the trolley wire from the power station, and is taken from the wire by the trolley wheel, and passes along down the trolley pole to the trolley stand, and onward through wire running to M. M. switch or overhead switch number 1. If the switch is closed, the path of the current is through the wire leading to M. M. switch or overhead switch number 2, and through the wire running to the fuse box and onward through wire connected to lightning arrester, passing into arrester and through a blow-out magnet coil, then through a wire connecting with wire in cable indicated by the letter T. This wire connects with terminals on connection board of each controller, and also with blow-out magnet coil of controller, through which the current passes, when the coil is in operation, and continues onward through a wire which is connected with the top contact finger of each controller.

Reverse Switch in G. E. Controllers, Types K-1, K-2, K-10 and K-11. The G. E. Controller reversing switch is constructed in the form of a cylinder and is also referred to as the "reversing cylinder." It is composed of some kind of insulating material, and there are 16 contact plates mounted upon the cylinder. Eight of these contact plates cause the forward direction of the armatures, and the other eight the backward. Beginning at the bottom of the reverse switch, eight of the contact plates of the reverse switch are connected in pairs, when the forward motion is used. These connections are imbedded in the insulating material of the switch, and consist of a heavy wire. Four pairs of contact plates are required for this connection of the two motors. The connections of motor number 1, are the first two from the bottom of the switch upward, and those of motor number 2 are the third and fourth pairs from the bottom.

The number 19 wire connection is at the bottom contact wiper of the first pair, and the A-1 lead connection is at the second contact wiper of the first pair. The third contact wiper, which is the first contact wiper of the second pair, is the AA-1 lead connection. The fourth contact wiper up 'on reverse switch is the F-1 lead connection, and is the second contact wiper of the second pair. The fifth contact wiper up is the number 15 wire and is the first wiper of the third pair. The sixth contact wiper up is the A-2 lead connection, and is the second contact wiper of the third pair. The seventh contact wiper up is the AA-2 lead connection, and is the first contact wiper of the fourth pair. The eighth contact wiper up is the F-2 lead connection, and is the second contact wiper of the fourth pair.

The other eight contact plates are put in alternate, instead of successive connection with contact wipers, being connected in pairs, when reversing for the backward motion: i. e. for the connection of motor number 1, the first and third are connected and then the second and fourth. For the connection of motor number 2, the fifth and seventh are connected and then the sixth and eighth.

The connection of number 19 wire is represented by the first contact plate, and the AA-1 armature lead by the third contact plate. The connection of the A-1 armature lead is represented by the second contact plate and the F-1 field lead by the fourth contact plate. The connection of No. 15 wire is represented by the fifth contact plate and the AA-2 armature lead by the seventh contact plate. The connection of the A-2 armature lead is represented by the sixth contact plate and the F-2 field lead by the eighth contact plate.

1. When controller handle is at first position the path of the current is through the first wire, R-1, connecting with the rheostat, and then onward through wire R-3. This wire connects with terminal designated as R-3 on each controller connection board, and that terminal connects with wire marked number 19 or the main circuit wire for the complete circuit of number 1 motor. This wire connects with the bottom contact finger of reverse cylinder switch. When reversing cylinder is thrown for forward movement of the car the path of the current is to the 2nd contact finger, and onward up on the reverse switch, through wire designated A-1. This wire connects with the brush holder for armature circuit of motor number 1. The current then follows its path through the armature circuit, passing out at opposite brush holder and onward through wire designated AA-1. This wire is connected with the third

contact finger on reverse switch. When the current passes out at the fourth contact finger up on reverse switch it passes through wire marked F-1. This wire connects with field circuit of motor number 1.

The current then leaves wire F-1 and continues on through wire marked E-1. This wire is the ground end wire for the complete circuit of motor number 1. Wire E-1 connects with the center bar of cut-out switch for motor number 1. The path of the current is then on to contact fingers marked E-1 and then through cylinder to wire marked 15. This wire is the main circuit wire for the entire connection of motor number 2, and it connects with the 5th contact finger up on the reverse switch. When the current leaves by the 6th contact finger on the reverse switch, it passes through the wire marked A-2. This wire connects with the brush holder for armature circuit of motor number 2. The path of the current is then on through armature circuit passing from opposite brush holder on through wire marked AA-2. This wire connects with the seventh contact finger on reverse switch. When current leaves reverse switch at the 8th contact finger it passes through the wire marked F-2. This wire connects with the field circuit of motor number 2. When leaving this wire the current flows through wire marked E-2, or the ground-end wire for the complete connection of motor number 2, and which connects with the main ground wire designated G, at the motor.

2. When controller handle is at second position the two motors are still in series just as when controller was at first position; but the path of the current is through wire R-2, which connects with the rheostatic circuit. On second position an increase of speed is obtained by

an increase of current as a part of the resistance is cut out.

3. When controller is at third position, the two motors are still in series and the circuit is the same as at the two preceding positions; but there ceases to be any rheostatic connection with the motor circuit, the path of the current leading directly to the motor terminals, and increasing the speed of motors by reason of the increase of current.

4. When the controller handle is at the fourth position, the two motors are still in series without exterior resistance; but the current is shunted from the field circuit of motor number 1, and carried to ground through the armature circuit of motor number 2, and the current which is shunted from the field circuit of motor number 2 passes through the main ground wire terminal in the controller to the ground.

An increase of current at armature terminals, which increases the speed of armatures, is obtained by the shunting of the field circuits of the two motors which decreases the field strength.

5. When the controller handle is at the fifth position the motors are changed to parallel, or multiple with resistance equal to about one half of the rheostatic panels, and the path of the current to the rheostat is through a wire marked R-2. The ground end wire of the complete connection of motor number 1 is, on this position, connected to the main ground wire in controller by the controlling cylinder. In this position the circuit of motor number 2 is in connection with the circuit of the main circuit wire of motor number 1; this wire being marked number 19, and is connected with the main circuit wire of motor number 2, which is

marked number 15. The wire marked E-2 is the ground end wire of the circuit of motor number 2, and remains in connection at motor with the main ground wire.

6. When the controller handle is at the sixth position the two motors are still in parallel or multiple; but without exterior resistance. The path of the current leads to the motor terminals direct, and the current passes simultaneously, through wire marked number 19 in controller, to circuit of motor number 1, and through wire marked number 15 to circuit of motor number 2. The connection of the contact finger marked R-4, holds in circuit the wires marked number 15 and number 19.

7. When the controller handle is at the seventh position, the two motors are still in parallel or multiple; but the field circuit has been shunted and the current shunted from the field circuit of motor number 1, passes through the main ground wire terminal in controller to the ground, and the current shunted from the field circuit of motor number 2 passes to the ground through the main ground wire in controller. Fig. 26 shows resistance in K controller.

Path ofthe Current Operating a car with G. E. type K-2 controller and two motors in series parallel with shunt accessory.

The Safe Running Positions on a G. E. type K-2 controller are 4, 5, 8 and 9, and are indicated by the long raised bars on the dial plate of controller. The unsafe running positions are 1, 2, 3, 6 and 7. They are the rheostatic or resistance points and are indicated by the short raised bars on dial plate.

The circuit of motor number 2 is completely cut out when changing the controlling cylinder to a parallel, from a series connection and the handle of controller is

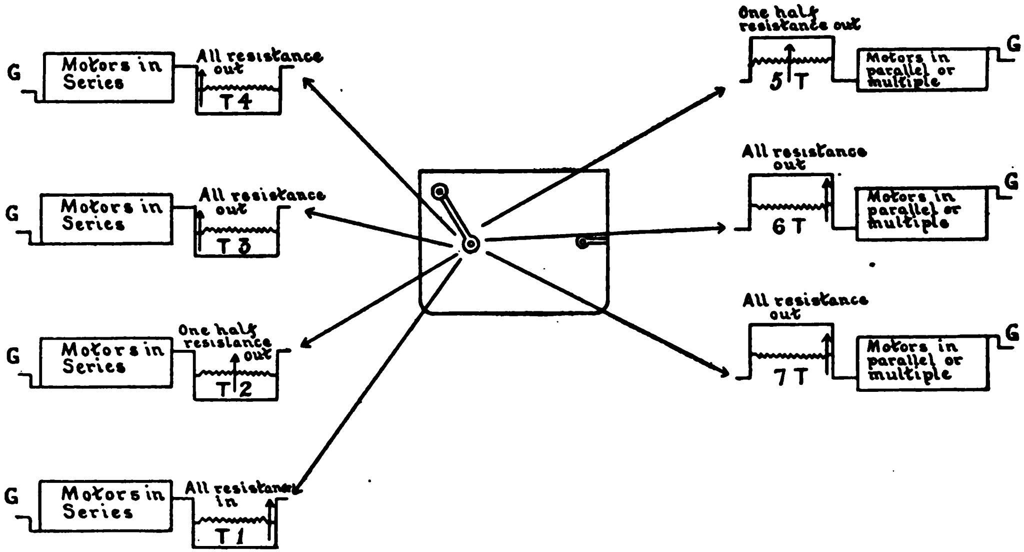


Fig. 26. Diagram showing the resistance in or out at each position; the total resistance being represented by the twelve inverted Vs forming the zigzag lines above. The amount of resistance at any position is indicated by an arrow running vertically through the point where resistance is cut out.

midway between the fifth and sixth positions. When the two motors are placed in multiple, the full connection is not made until the sixth position is reached. Through wires L-1 and L-2, the ground ends of shunt are placed in connection with controller and the shunt resistance employed with motors is generally tapped from the field leads on the positive side of the field circuit. Fig. 27 shows resistance on K-2 controller.

The current flows through the trolley wire from the power station, and is taken from the wire by the trolley wheel, and passes along down the trolley pole to the trolley stand, and onward through wire running to M. M. switch or overhead switch Number 1. If the switch is closed the path of the current is through the wire leading to M. M. switch or overhead switch number 2, and through the wire running to the fuse box, and onward through wire connected to lightning arrester, passing into arrester and through a blow-out magnet coil, then through a wire connecting with wire in cable indicated by the letter T. This wire connects with terminals marked T on connection board of each controller, and also with blow-out magnet coil of controller, through which the current passes when the coil is in operation, and continues on through a wire which is connected with the top contact finger of each controller.

1. When controller handle is at first position the path of the current is through the first wire, R-1, connecting with the rheostat, and then onward through wire R-4. This wire connects with terminal designated as R-4 on each controller connection board, and that terminal connects with wire marked number 19, or the main circuit wire for the complete circuit of number 1 motor.

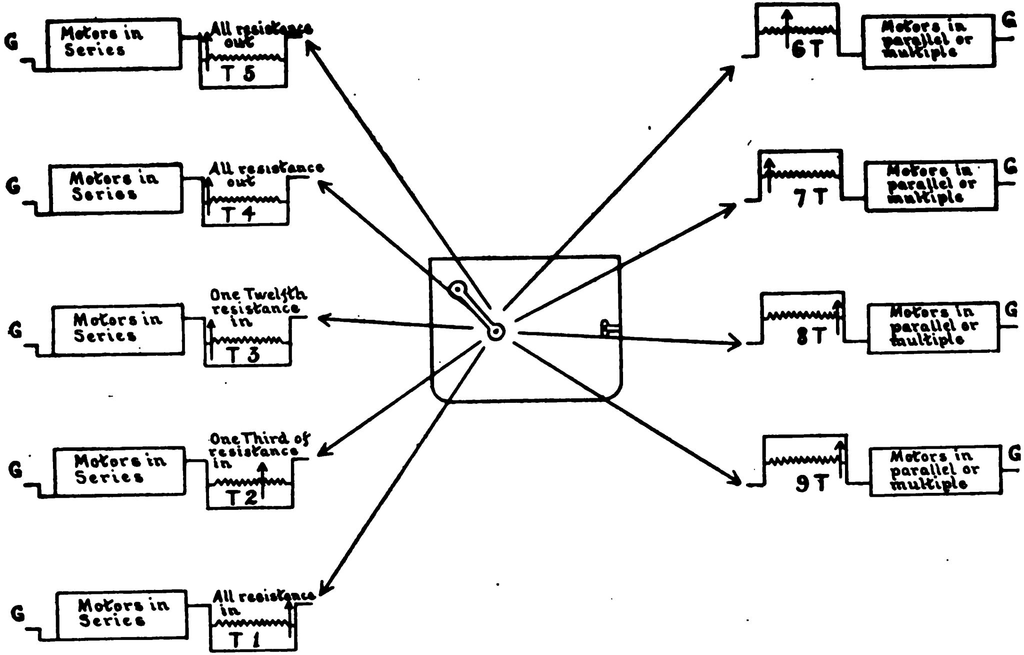

G
Motors in Series
All resistance out
T 5
G
Motors in Series
All resistance out
T 4
G
Motors in Series
One Twelfth resistance in
T 3
G
Motors in Series
One Third of resistance in
T 2
G
Motors in Series
All resistance in
T 1
6T
Motors in parallel or multiple
G
7T
Motors in parallel or multiple
G
8T
Motors in parallel or multiple
G
9T
Motors in parallel or multiple
G

Fig. 27. Diagram showing the resistance in and out at each position; the total resistance being represented by the twelve inverted Vs forming the zigzag lines above. The amount of resistance at any position is indicated by an arrow running vertically through the point where resistance is cut out.

This wire connects with the bottom contact finger of reverse cylinder switch. When reversing cylinder is thrown for forward movement of the car, the path of the current is to the second contact finger and onward upon the reverse switch, through wire designated A-1. This wire connects with the brush holder for armature circuit of motor number 1. The current then follows its path through the armature circuit, passing out at the opposite brush holder and onward through wire designated AA-1. This wire is connected with the third contact finger on reverse switch. When the current passes out at the fourth contact finger upon reverse switch, it passes through wire marked F-1. This wire connects with the field circuit of motor number 1. The current then leaves wire F-1 and continues on through wire marked E-1. This wire is the ground end wire for the complete circuit of motor number 1. Wire E-1 connects with the center bar of cut-out switch for motor number 1. The path of the current is then onto contact fingers marked E-1, and then through cylinder to wire marked 15. This wire is the main circuit wire for the entire connection of motor number 2, and it connects with the fifth contact finger upon the reverse switch. When the current leaves at the sixth contact finger on the reverse switch, it passes through the wire marked A-2. This wire connects at the brush holder for armature circuit of motor number 2. The path of the current is then on through armature circuit, passing from opposite brush holder on through wire marked AA-2. This wire connects with the seventh contact finger on reverse switch. When the current leaves switch at the eighth contact finger, it passes through the wire marked F-2. This wire connects with the field circuit of motor number 2. When leaving this wire the current flows through wire marked E-2 on the ground end wire for the complete circuit of motor number 2 and which connects with the main ground wire designated G at the motor.

2. When the controller handle is at the second position, the two motors are still in series, just as when controller was at the first position; but the path is through wire R-2, which connects with the rheostatic circuit. On second position an increase of speed is obtained by an increase of current as a part of the resistance is cut out.

3. When the controller handle is at the third position, the two motors are still in series and the circuit is the same as at the two preceding positions; but the path of the current is through wire marked R-3, which connects with the rheostatic circuit. On the third position there is an increase of speed over that developed on the second position, as all but one-twelfth of the resistance in connection with motor circuits has been cut out.

4. When the controller handle is at the fourth position, the two motors are still in series and the circuit is the same as at the three preceding positions; but the current flows directly to the motor terminals, as all rheostatic connection with motor connection has been cut out. This gives an increase of current to motor terminals, and a greater increase of motor speed over that held at the preceding positions.

5. When the controller handle is on the fifth position the two motors are still in series, without exterior resistance; but the current is shunted from field circuit of motor number 1, and carried to the ground through the armature circuit of motor number 2, and the current which is shunted from the field circuit of motor number 2 passes through the main ground wire terminal in the

controller to the ground. An increase of current at armature terminals, which increases the armature speed, is obtained by the shunting of the field circuits of the two motors, which decreases the field strength.

6. When the controller handle is at the sixth position the two motors are changed to parallel or multiple with resistance equal to about one-third of the rheostatic panels, and the path of the current to rheostat is through a wire marked R-2. The ground end wire marked E-1 of the complete circuit of motor number 1, is on this position connected by the controlling cylinder, to the main ground wire in controller. In this position the circuit of motor number 2 is in connection with the main circuit wire of motor number 1; this wire being marked number 19 and is connected with the main circuit wire of motor number 2, which is marked number 15. E-2 is the ground end wire of the circuit of number 2, and remains in connection at motor with the main ground wire.

7. When the controller handle is at the seventh position the two motors are still in parallel, or multiple as in the preceding position; but all except one-twelfth of the resistance is cut out of the circuit. The path of the current is to the rheostat through wire R-3, causing an increased armature speed, by reason of an increase of current at motor terminals.

8. When the controller handle is at the eighth position, the two motors are still in parallel, or multiple; but without exterior resistance. The path of the current is straight to the terminals of the motors, passing to the circuit of motor number 1 through the wire marked 19 in controller and to the circuit of motor number 2 through the wire marked 15; the current entering both motor circuits at the same time, and the wires through

which the current passes to motor circuits are held in circuit by the connection of contact finger R-4.

9. When the controller handle is at the ninth position, the two motors are still in parallel or multiple as at preceding position; but the field circuit has been shunted, and the current shunted from the field circuit of motor number 1 passes through the main ground wire terminal in controller to the ground, and the current shunted from the field circuit of motor number 2 passes to the ground through the main ground wire in controller.

PATH OF THE CURRENT OPERATING A CAR WITH A G. E. TYPE K 10 OR 11 CONTROLLER.

There is no variation with this type of controller in the path of the current from the trolley wire to the trolley contact wiper in controller from that followed by the current in the K, K-1 or K-2 controllers.

1. When the controller handle is at the first position the path of the current is through a wire marked R-1, or the first wire connected to the rheostat or resistance. At a wire marked R-5 it passes from the resistance circuit. This wire connects with terminal R-5 on connection boards of the controllers and this terminal connects with a wire marked 19, the main wire of the complete circuit of motor number 1, and this wire connects with the bottom contact finger of reverse cylinder or switch. The path of the current, when reversing cylinder is pushed forward for the car to go ahead, is to the second contact finger upon reverse switch, and leaving this point flows through wire marked A-1. This wire is connected to the brush holder of armature circuit of motor number

1, through which it flows onward through opposite brush holder to wire marked AA-1. This wire is connected upon reverse switch with the third contact finger. The current then leaves reverse switch at the fourth contact finger, and continues on through wire marked F-1. This wire connects with field circuit of motor number 1, and the current passes from it through the ground end wire of the entire circuit of motor number 1. This wire is marked E-1, and is connected with the right hand bar of cut-out switch for motor number 1. The path of the current then passes through a wire connecting with contact wipers E-1, and those which connect through the cylinder with wire 15. This wire, 15, is the main circuit wire for the whole circuit of motor number 2, and connects upon the reverse switch with the fifth contact wiper. The path of the current is then, after leaving the reverse switch by the sixth contact wiper, through a wire marked A-2, which connects with the brush holder of armature circuit for motor number 2, and onward through the armature circuit, through opposite brush holders by a wire marked AA-2. This wire connects upon reverse switch with the seventh contact wiper, and the current leaves at the eighth contact wiper on reverse switch, and passes through wire marked F-2 to the field circuit of motor number 2. When leaving the field circuit the current continues on through a wire marked E-2. This wire is the ground end wire of the whole circuit of motor number 2, and connects at motors with the main ground wire marked G.

2. When the controller handle is at the second position the motors are still in series, with no variations in the circuit from preceding position; but the path of the current is now through wire marked R-2 instead of R-1;

and R-2 is connected with the rheostatic circuit. About one-fourth of the resistance in connection with motor circuits is cut out on this position, which increases the current to motor terminals, and causes an increase of motor speed.

3. When the controller handle is at third position the motors are still in series, with no variation in the circuit from preceding positions; but the path of the current is through wire marked R-3, instead of through wires R-1 and R-2, and R-3 is connected with the rheostatic circuit. About one-half of the resistance with motors in circuit is cut out on this position, which increases the current to motor terminals and causes increase of motor speed.

4. When the controller handle is at the fourth position the motors are still in series, with no variation of the circuit from the preceding positions; but the path of the current is now through a wire marked R-4 instead of through wires R-1, R-2 or R-3, and R-4 is connected with the rheostatic circuit. About three-quarters of the resistance with motors in circuit is cut out on this position, which increases the current to the motor terminals and causes increase of motor speed.

5. When the controller handle is on the fifth position the motors are still in series, with no variation of the circuit from the preceding positions; but all rheostatic resistance has been cut out of the motor circuit, and the path of the current runs straight to terminals of motor, which increases the current at terminals, and causes a further increase of motor speed than that obtained at fourth position.

6. When the controller handle is at the sixth position the two motors are changed to parallel, or multiple with

resistance equal to about three-quarters of the rheostatic panels, and the path of the current through the rheostat is by a wire marked R-2. The ground-end wire marked E-1 of the complete circuit of motor number 1, is on this position connected by the controlling cylinder to the main ground wire in controller. In this position the circuit of motor number 2 is in connection with the main circuit wire of motor number 1, this wire being marked number 19, and is connected with the main circuit wire of motor number 2, which is marked number 15. The ground-end wire E-2 of the circuit of motor number 2 remains in connection at the motor with the main ground wire.

7. When the controller handle is at the seventh position the two motors are still in parallel, or multiple, with one-half of resistance in circuit with motors, and the path of the current is to the rheostat by a wire marked R-3, which increases the current at motor terminals, and causes a still further increase of armature speed.

8. When the controller handle is on the eighth position the motors are still in parallel, or multiple with about one-quarter of resistance in circuit with motors, and the path of the current is to the rheostat through a wire marked R-4, which increases current at motor terminals, and causes a still further increase of armature speed.

9. When the controller handle is at the ninth position the two motors are still in parallel or multiple; but there is no exterior resistance and the path of the current leads straight to the terminals of motors, passing simultaneously through a wire marked number 19 to circuit of motor number 1, and through a wire

marked 15 to circuit of motor number 2, both of these wires being kept in circuit by contact wiper R-5 connection.

The fifth and ninth running positions of the G. E. type K-10 and K-11 controller are the safe ones, and the unsafe ones, which are the rheostatic or resistance points, are 1, 2, 3, 4, 6, 7. The long raised bars on the dial plate of controller indicate the safe running positions and the short raised bars indicate the rheostatic points. Fig. 28 shows resistance on K-10 controller.

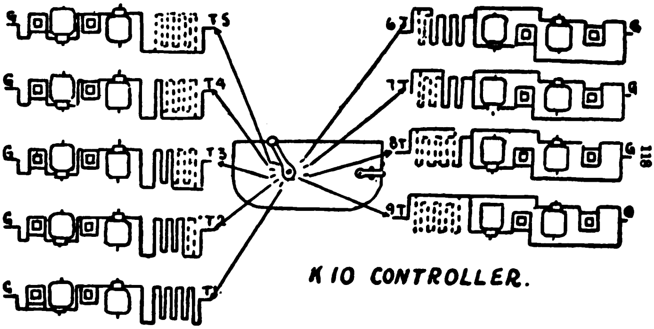
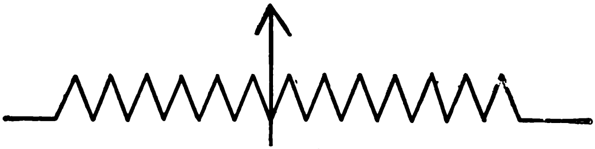


Fig. 28.

1st	position,	all	resistance	in.
2d	"	¾	"	"
3d	"	½	"	"
4th	"	¼	"	"
5th	"	all	resistance	out.
6th	"	¾	"	in.
7th	"	½	"	"
8th	"	¼	"	"
9th	"	all	resistance	out.

INSTRUCTIONS FOR MAKING DIAGRAMS FOR CONTROLLERS SHOWING THE RESISTANCE, ETC.

See the diagrams of K and K-2 controllers, Figs. 26 and 27, and in reproducing them make the zigzag representing the resistance with twelve V-shaped spaces as follows:



and where resistance is cut off run arrow through. Then make the same kind of diagram for K-10 or K-11 controller and No. 28 A Westinghouse controller as for K and K-2, with the same explanation underneath each as is under K and K-2. Change No. 28 A Westinghouse to show zigzag resistance same as K, K-2 and K-10.

Path of Current operating a car with Westinghouse 28-A controller does not vary from that taken by the current operating the G. E. controllers until after the trolley contact wiper in controller has been reached.

The motors are in series on the first position and operate in conjunction with No. 46 "diverters," which correspond functionally with the rheostat or resistance in the G. E. system.

The backward movement of the car is obtained, when using the reverse switch, by the change occurring in polarity of motors on field circuit; but without any change in polarity of the armature circuit on either backward or forward motion.

1. When controller handle is at first position, the path of the current leads from trolley contact wiper to R-1 contact wiper, and on through a wire to di-

verter No. 2. At R-3 terminal of rheostatic, or resistance circuit, the current passes to arc coil in controller by a wire connected with terminal R-3. The negative lead of the arc coil is connected with the lower right side corner binding post of cut-out switch for motor No. 1, and that binding post is connected with the top right side binding post of same cut-out switch, which is connected with the left side binding post of the reverse switch contact wiper, which is connected with the cable lead F-1+ and which connects with cable lead F-1—. This last mentioned wire connects with field circuit of motor No. 1. When leaving field circuit of motor No. 1 the path of the current is through wire F-1+, which connects with F-1— terminal in controller, and on through connection to binding post F-1— of reverse switch and then to A-1+ binding post and then to wire A-1+ in cable, this being the connection with the positive brush-holder of armature circuit for motor No. 1. The current then leaves the armature circuit at the opposite brush holder, and passes through wire A-1— to terminal A-1— in controller, which is connected to the top left side binding post of cut-out switch for motor No. 1; that binding post being connected to the bottom left side binding post of same switch, and which is connected with R-4 terminal and contact wiper. The path of the current is now through wire marked R-4 connecting with No. 1 diverter, which it leaves at terminal R-5. This terminal is connected through the cylinder with the main circuit wire for the whole connection of motor No. 2. This circuit wire connects with the bottom left side binding post of cut-out switch for motor No. 2, which in turn connects with the top left side binding post of the same switch, this switch being in connection with the right side binding post of reverse switch. The path of the current is now to binding post F-2+, which connects with F-2— wire in cable. This wire connects with the field circuit of motor No. 2, and the current leaves the field circuit through wire F-2+ at terminal. This wire connects with wire F-2— in controller, which is connected through reverse switch to binding post A-2+. After leaving this point, the current passes through wire A-2—, connecting with the positive brush-holder of the armature circuit for motor No. 2 and passes out of circuit at opposite brush-holder through wire A-2+. This wire connects at motor with the main ground wire, which completes the path of the current.

2. When the controller handle is on the second position, the motors are still in series, and the path of the current is the same as at first position, passing through diverter No. 2, diverter No. 1 being cut out of circuit, which gives an increase of current to terminals of motors, causing an increase of armature speed.

3. When the controller handle is at the third position, the motors are still in series as on the preceding positions, with no variation in the path of the current; but only about one-half of the resistance from No. 2 diverter is in the circuit, which increases the current at terminals of motor, and causes a further increase of armature speed.

4. When the controller handle is on the fourth position, which is the first safe running position and marked on dial plate "one-half speed," the motors are still in series as on preceding positions, with no variation in the path of the current, but both diverters are cut out of the circuit and an increase of current passing direct to

terminals of motors causing a further increase of armature speed.

5. When the controller handle is on the fifth position, the motors are changed to parallel or multiple, and diverter No. 2 is in connection; the diverter wires R-4 and R-5 acting as ground connection for the circuit of motor No. 1. Wires R-4 and R-5 are connected with main ground wire in controller. The main circuit wire of the connection of motor No. 1 holds the circuit of motor No. 2 in connection.

6. When the controller handle is at the sixth position, the motors are still in multiple, with no variation in the path of the current from the preceding position; but the current, which passes to the diverter through wire marked R-2, is increased by a reduction of about one-half the rheostatic or diverter resistance, and this increase of current to terminals of motors causes an increase of armature speed.

7. When the controller handle is at the seventh position, which is the second safe running position, and marked on the dial plate "full speed," the motors are still in multiple, with no variation from the two preceding positions in the path of the current; but all diverter resistance is cut out, the current passing straight to terminals of motors, causing armatures to attain their maximum speed. Fig. 29 shows resistance on Westinghouse 28-A controller.

NO. 28-A WESTINGHOUSE CONTROLLER.

First Position—Resistance all in on both motors.

Second Position—Resistance all in on motor No. 2 and out on motor No. 1.

Third Position—Resistance one-half out on motor No. 2 and all out on motor No. 1.

Fourth Position—Resistance all out on both motors.

Fifth Position—Resistance all out on motor No. 1 and all in on motor No. 2.

Sixth Position—Resistance all out on motor No. 1 and one-half out on motor No. 2.

Seventh Position—Resistance all out on both motors.

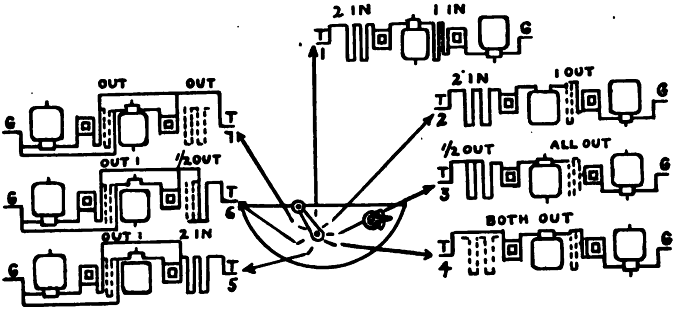


Fig. 29. No. 28A Westinghouse Controller.

The Commutator is a device composed of a number of drop forgings, or copper castings. These castings, which are styled segments, are separated from each other by an insulation of mica, and are generally assembled around a tube and held in position by nuts screwed on to the ends of the tube. The wear upon the copper and mica under the action of the brushes is about even, and for this reason, together with its superior insulating qualities, mica is much in favor in commutator construction. Twenty volts is about the maximum voltage between commutator segments. With uniformity of voltage distribution, a machine of 500 volts with a closed series winding would have between contiguous poles 25 bars;

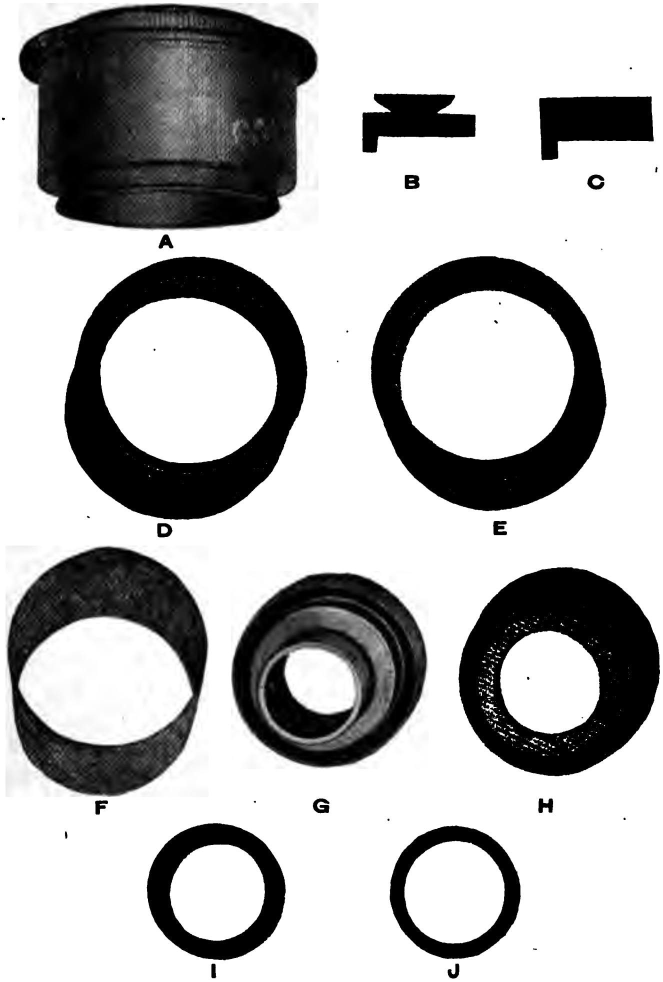


Fig. 30.

a. Commutator complete.
b. Commutator bar, unfinished.
c. Mica segment between commutator bars.
d. Rear mica V-ring.
e. Front mica V-ring.
f. Mica bushing, 5" x 9⅛" x 9¼".
g. Commutator bushing.
h. Commutator steel V-ring.
i. Forged steel commutator nut.
j. Sheet brass washer.

or 100 bars for a four-pole machine. The greater capacity of the motor, the greater number of segments required, e. g.: The G. E. 64 motor has 105 bars; the G. E. 55 railway has 141; the Westinghouse 50-E and 56 motors have respectively 165 and 117 bars; the G. E. 1,000 motor has 93. For railway motors a greater number of commutator segments is required to obviate flashing, should the motor circuit be suddenly interrupted.

Fig. 30 shows Westinghouse commutator and parts.

The terminals of armature conductors are soldered into projections of the commutator segments.

The complete commutator is made fast by means of a key to the armature shaft.

Ordinarily the commutator is built up separately and then keyed to the shaft. This is done to lessen the cost of construction when a new commutator is fitted to an old motor.

Fig. 31 shows commutator in sectional view.

FIELD MAGNETS AND FIELD FRAME.

The field coils of railway motors are wound with strip copper in order to reduce the 1^2-R losses to the lowest degree. The magnetic field in which the armature rotates is obtained by the flow of the electric current through the strips of copper with which the field coils are wound. These coils are mounted upon iron cores. The Westinghouse 50-E motor is wound with copper 5/64″x1½″. The entire current which flows through a series motor enters the field coils, and to obviate overheating, the copper strips are employed in the construction of machines designed for sufficient power.

The flux which passes in a magnetic circuit equals the magneto-motive force divided by the reluctance of the circuit. The flow of magnetic flux, and the flow of current are subject to analogous laws.

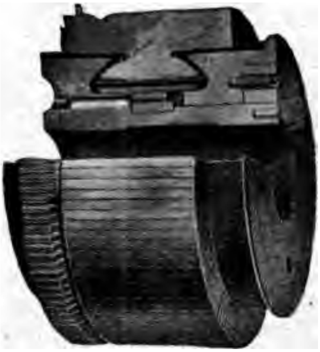


Fig. 31.

Variation in Speed. A motor constructed to operate in a 300 volt circuit will develop twice the speed at same current input in a 600 volt circuit, allowing a slight variation due to change of flux.

Fig. 32 shows a Westinghouse field coil complete, with some of the principal parts.

SUSPENSION MOTORS.

In the use of motors suspended from car trucks, the motors are generally constructed in a manner to permit the axle of the car wheels to revolve in bearings located in one side of the motor frame. On the motor armature axle a pinion is driven. This pinion consists of a

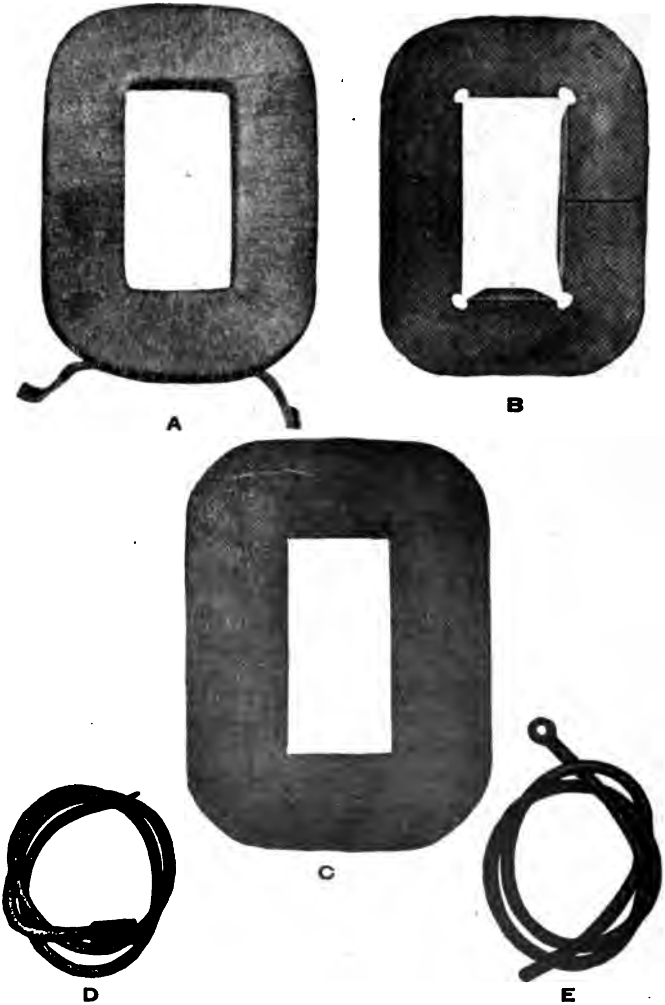
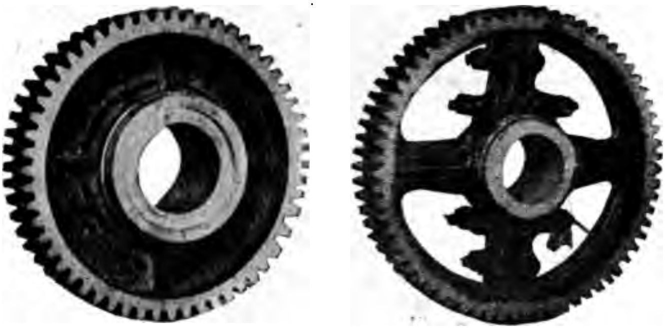


Fig. 32.

a. Field coil complete.
b. Coil shield.
c. Oil duck coil protector.
d. Double coil hanger.
e. Single coil hanger.

small gear. A large gear (Fig. 33) is mounted on the axle of car wheels. Both gears are protected by a gear case (Fig. 34) and mesh at a tangent regardless of their relative positions.



Solid Gear. Split Gear.

Fig. 33.

Fig. 35 shows the pinion engaging the gear wheel.

The several methods of suspension in general use are known as yoke, side or parallel bar, cradle and nose suspensions. Figs. 36, 37 and 38 show the parallel, nose and cradle suspensions.

The side or parallel bar suspension, Fig. 36, is effected by fastening two parallel bars to the car truck from which the motor is suspended on springs at each end.

The nose suspension is so devised as to divide the weight of the motor between the car axle and the truck. To effect this the motor frame is cast with a projection,

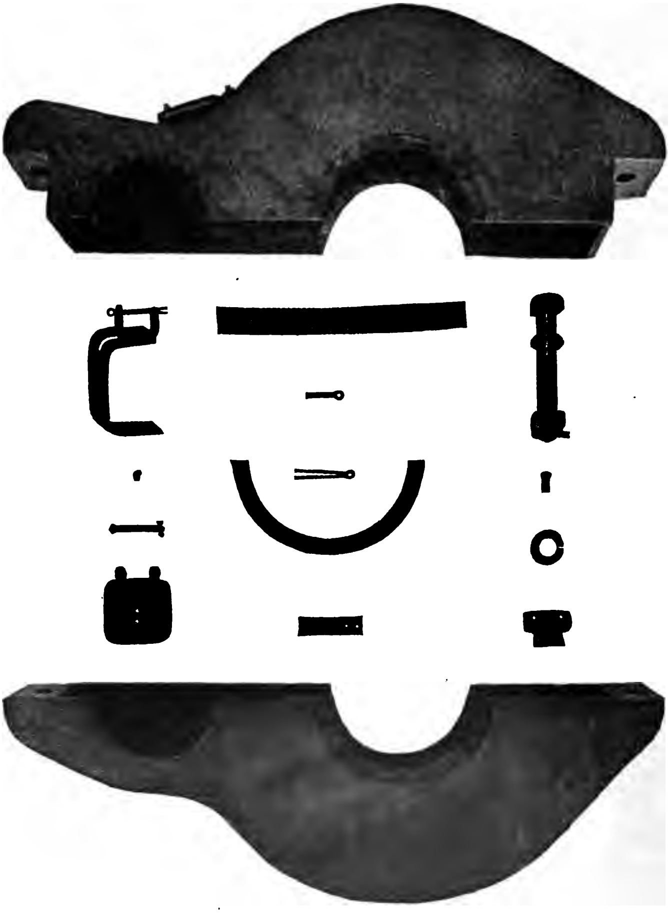


Fig. 34. Gear Case and Parts.

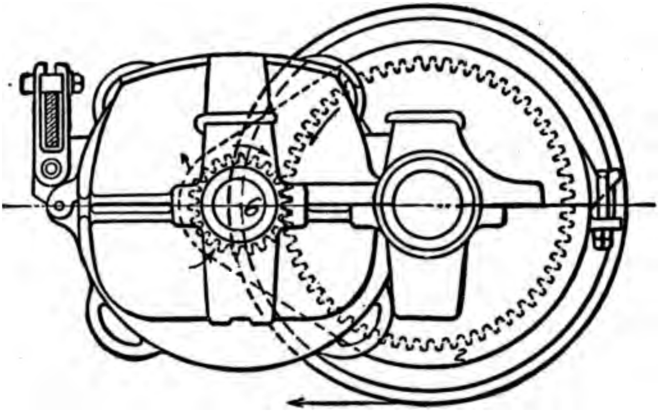


Fig. 35.

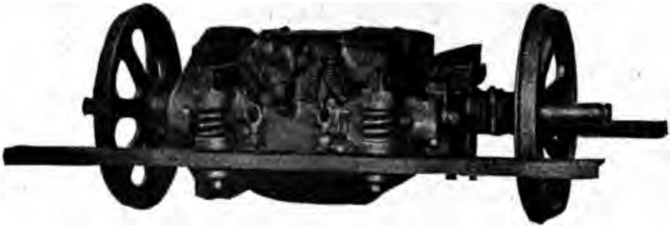


Fig. 36. Parallel Bar Suspension.

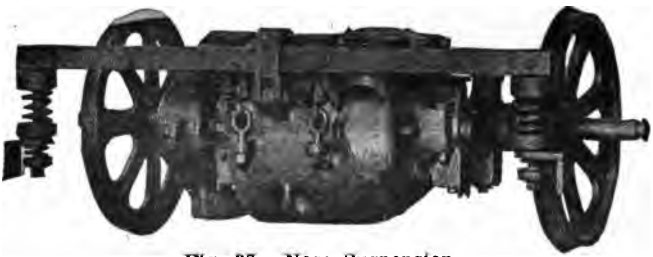


Fig. 37. Nose Suspension.

termed "nose." This projection, by means of a stout link, is made fast to the truck.

The cradle suspension (Fig. 38) is so devised as to take the weight of the motor from the bearings. Fastened to the truck is a V-shaped device or bar; in other respects it is similar to the parallel suspension.

Fig. 39 gives diagram of yoke suspension.

Fig. 40 gives diagram of nose suspension.

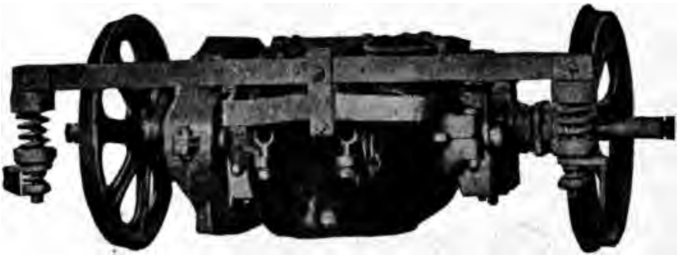


Fig. 38. Cradle Suspension.

MOTOR OF THE BOX FRAME TYPE.

This type of motor, designed for heavy service, was introduced by the General Electric Company and is known as the G. E. Box Frame Type. In this type of motor the magnet frame consists of a one-piece hollow casting with both ends open, instead of a split frame, and the armature is made fast to the field frame by end plates. In the frame motor a pit may be dispensed with in removing the armature, as it can be taken from the motor frame at one side. There is a continuous magnetic circuit throughout the frame and the construction is such as to prevent the leakage of oil and water into body of motor. The motor has a capacity of 125 h. p. based upon

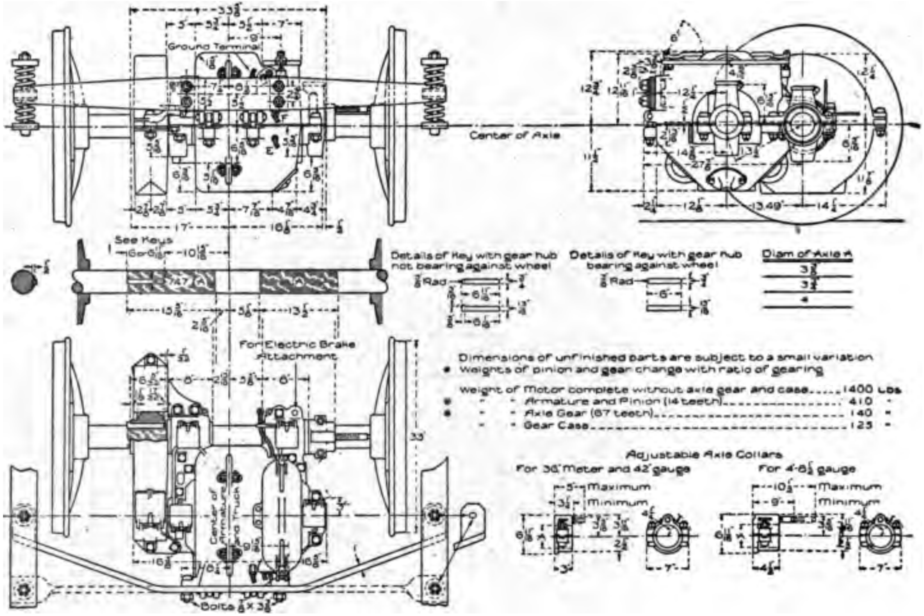

Ground Terminal
Center of Axle
See Keys
For Electric Brake Attachment
Center of Armature and Truck
Bolts $\frac{5}{8}$ × $3\frac{3}{8}$
Details of Key with gear hub not bearing against wheel
$\frac{7}{8}$ Rad
Details of Key with gear hub bearing against wheel
$\frac{7}{8}$ Rad
Diam of Axle A
$3\frac{5}{8}$
$3\frac{3}{4}$
4
Dimensions of unfinished parts are subject to a small variation
* Weights of pinion and gear change with ratio of gearing
Weight of Motor complete without axle gear and case ...... 1400 Lbs
* " " Armature and Pinion (14 teeth) .... 410 "
* " " Axle Gear (67 teeth) .... 140 "
" " Gear Case .... 125 "
Adjustable Axle Collars
For 36" Meter and 42" gauge
Maximum
Minimum
For 4'-8½" gauge
Maximum
Minimum

Fig. 39. Yoke Suspension.

a rise of temperature of 75° above surrounding atmosphere, after a run of one hour at full load. The magnet frame is in form of a cube and is cast in one piece of soft

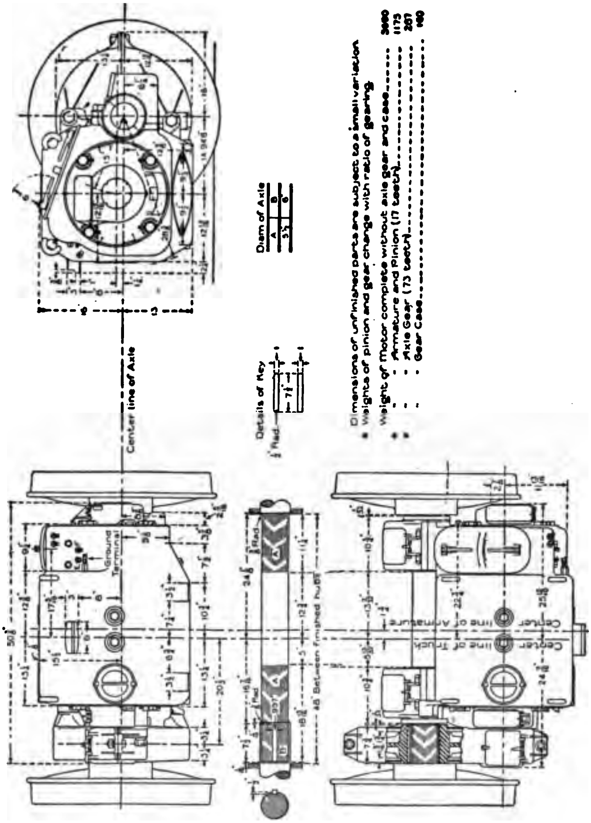

Center line of Axle
Diam of Axle
Details of Key
Dimensions of unfinished parts are subject to a small variation
* Weights of pinion and gear change with ratio of gearing
Weight of Motor complete without axle gear and case...... 3080
* " Armature and Pinion (17 teeth)........ 1175
* " Axle Gear (73 teeth)........ 287
" Gear Case........ 180
Ground Terminal
Center line of Armature
Center line of Truck
48 Between finished hubs

Fig. 40. Nose Suspension.

steel. The motor is entirely water tight, as the frame heads containing the bearings are bolted into the openings. In the ends of the cube, through the borings the field coils and armature are placed in position. The coil is kept from penetrating into the motor body by oil deflectors on the bearings. The armature is patterned like the series drum barrel type. The windings consist of 39 coils, five single coils of one turn being employed for each one. All the coils in a slot are protected on the exterior with mica and tape, the conductors being insulated in groups of five with mica. At the rear of the armature the conductors are cross-connected, and to provide for rewinding, the top and bottom conductors are joined by turned copper clips which may readily be removed. The windings are designed to withstand high temperatures without injury, and are to a great extent fireproof. The 195 segments of hard drawn copper of which the motor is composed are insulated with mica, and the motor has four field coils wound on metal spools with strip copper and insulated with asbestos cloth and mica. It is of the nose suspension type and has a clearance of 3½″ when mounted on 33″ wheels. The total weight of motor is 3,966 pounds without gear and gear case.

SERIES MOTORS.

The field excitation in the series motor is derived from the main current, which flows through the field coils that are in series connection with the armature. The excitation is in proportion to the supply of current to the motor, and but for the saturation of the magnetic circuit, and internal resistance drop, at terminal constant voltage, the speed would be inversely as the amperes input, where, at 50 per cent of full load, the speed is double that at full load. Series motors, however, in practice are generally proportioned to possess a highly saturated magnetic circuit at full load current and the speed curve takes the form of the full line curve. The principal employment of series motors is for locomotion, and such other work as requires a high starting torque, as their loads are generally of an intermittent character, and consequently must be proportioned with much higher current densities in armature, and field coil windings for their normal rated load than would be required by motors constructed to carry their full load during the whole time in operation. For a number of years there has been in generally accepted use an arbitrary basis of rating for car motors, which defines the nominal capacity as the horse power output, giving a rise of 75 per cent of the hottest accessible part after running continuously for one hour on a testing stand at rated voltage. Electric car motors in actual service are required to carry an average load of only some 35 per cent, or less of their rated load, and for this reason they should be built for higher efficiency at light loads. They are capable of being proportioned to produce this result, as the field excitation increases from a very small amount at no load with the square of the load, and is a component part of the "variable losses" instead of being a component of the "no load." The gearing losses are to be reckoned with, however, in motors for light work, as it comes in, and considerably increases the "no load" losses; but large, direct connected series motors are of very high efficiency at light loads. Aside from considerations bearing only on motor and gearing, it should be borne in mind that motors which are subject to considerable losses in external resistances when starting, require auxiliary controlling apparatus.

MOTOR CONTROL.

In its least complex application the control is affected by a resistance in series with the motor, which is varied in amount in proportion to the load and the required speed. By the means of "series parallel" control greater economy is obtained. This provision requires two or more motors, or two independent armature windings and commutators per motor. The two motors are connected in series for low speeds at starting, and require less exterior resistance and expenditure of energy than is required by the rheostatic method. The motors are placed in parallel for the higher speeds, first with and then without resistances in series.

No really high efficiencies are obtained at starting, even by the series parallel methods of control, and they have been modified from time to time by the introduction of a diverting shunt to the series winding, thus obtaining an independent control of the field strength; but the prevailing belief is that a weakening of the field impairs the commutation efficiency, and therefore the advantageous application of the diverting shunt is questionable. With a more intimate acquaintance with occurrences during commutation, and broader experience in motor design, the features of motor control, and compound wound motors, in connection with the series parallel system, may insure more satisfactory results in commutation and further increase of efficiency in the future.

ELECTRIC CAR EQUIPMENT.

The selection of electric equipment for motor cars, whether operated singly or in trains, requires special consideration of the following points: The loads to be handled; the maximum speed that could be depended upon; whether all axles of the motor cars should be equipped; whether all cars of a train should be motor cars; what the motor characteristics, the ratio of gearing, and what the wheel diameters should be.

The main object should be to provide uniform equipment, so that any car may be devoted to any required class of service without discrimination. The motor equipment should be made with a view to efficiently handle traffic under all the varying conditions of train weight and schedule speed which may occur in the operation of a road.

An apt illustration may be found in the selection of the electric equipment of the Long Island Railroad.

It was demonstrated by investigation and experiment that the greatest flexibility was to be obtained from a two-motor car equipment using the most powerful motors practicable. The limitations were determined by the dimensions of the largest trucks which the tunnel and curve clearances would permit to be used. On this road the physical conditions of the road restricted the wheel base of the motor truck to 6′ 8″, which restricted the size of the motor to 200 h. p., and the study of the power of endurance of the motor to resist overheating, and the study of conditions was therefore reduced to an examination of the characteristics and gear ratio most suitable for this motor.

A series of speed tests were made by this road at the outset, for the purpose of comparing the time which they desired to be met by electrical equipment; the actual running time, and that laid down in the time tables. An ordinary passenger coach was fitted with speed-recording devices and a number of speed curves were obtained. The best performance of a relatively light steam locomotive train, weighing 171.9 tons with the locomotive is shown in Fig 41 and indicates that for all average lengths of runs between stops in suburban service up to about two miles the electric train is faster; the difference

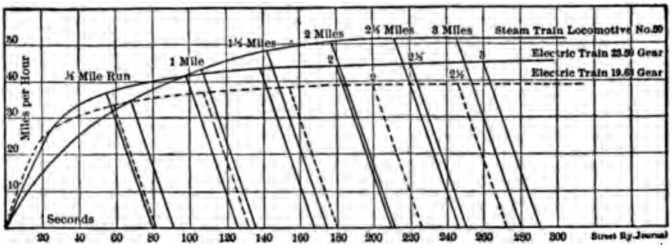


Fig. 41. Speed Time Curves.

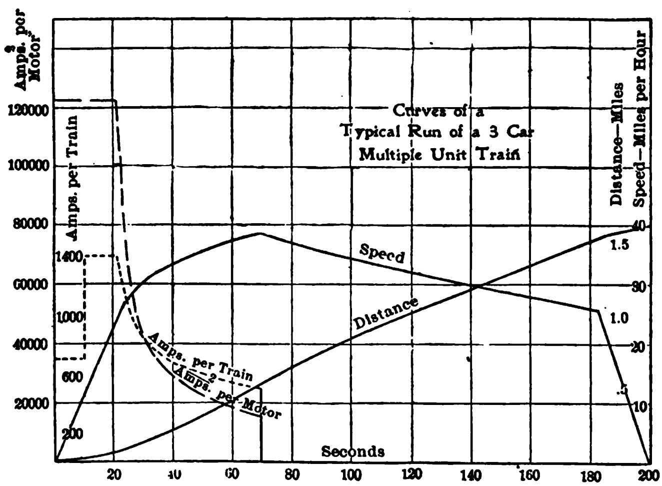


Fig. 42. Curves of a Typical Run of a Three-Car Multiple-Unit Train.

in running time of an equivalent electric train is shown in diagram (Fig. 41).

Fig. 42 shows the curves of a typical run of a three-car multiple unit train.

There was considerable work done in the early stages in comparing results obtained by former experiments, with a view to determining the train resistance which had to be properly assumed, in order to compute the speed of trains. With this data secured, the next step was to obtain data as follows: The schedule speed that could be maintained by certain motor and train combinations; the heating effect upon the motors when run continuously through the cycles of operation representing the average length of run, and the minimum permissible lay-over at the end of a run, for trains in continuous operation, and lastly the power consumption of the system with average, and maximum service.

The schedule speeds were derived directly from the speed time curves. The heating effect developed in each motor was obtained by computing the ''square root of the mean square'' current per motor, averaged over the entire time of any given run or succession of runs and comparing this with the limited value set by the manufacturers for the motor selected. The power consumption was computed from the current time curve corresponding to each speed time curve. The time distance curve was used to determine the location of the amount of current at any instant, thus enabling the ready computation of third rail and track drop and the distribution of the load between sub-stations. (See Fig. 42 for the three curves.)

The general result of the motor computations, as determining the size of the car equipment, was that a medium gear ratio (25:58 for the No. 113 Westinghouse motor) was decided upon and the number of motor cars and trailers per train was adopted as shown in the following table:

Length of Train	Local Trains		Express Trains	
	Motor Cars	Trailers	Motor Cars	Trailers
2 cars	2	0	1	1
3 "	2	1	2	1
4 "	3	1	2	2
5 "	3	2	3	2
6 "	4	2	3	3
7 "	4	3	4	3
8 "	5	3	4	4

The No. 113 Westinghouse motor was the first motor built by that company to use the diagonally divided field frame. With this frame the armature can be taken out without removing the motor from the truck, by lifting off the top half of the frame; or the motor can be lifted entirely from the truck by removing the gear case and axle cap. Nose suspension is employed, and the motor is oil lubricated from below. The pinion has twenty-five teeth 2½″ pitch and is cut from a solid steel forging. It is keyed to a tapered seat on the armature shaft and held in place by a nut and lock washer. The gear has 58 teeth, and is machined from solid cast steel and pressed and keyed to the axle. The diameter of the gear seat is 7 13/16″ and the face of the gear is 5¼″ wide. The gear case is of malleable iron, divided into halves horizontally, and supported at both the front and rear ends by lugs projecting from the motor frame and housing.

MULTIPLE UNIT SYSTEM OF CONTROL.

Among the most recent systems of the multiple unit control is one known as the Dick-Kerr system, which was recently installed on the Southport Electric Railway in England. This system of control presents so many new features that a comprehensive knowledge of its operation cannot but prove of educational value to the student, as well as to the professional electrical railway operative.

The system is applicable to any electric train using d. c. motors, and is a direct electro-magnetic system with series solenoids actuated by the negative or return current of the train motors.

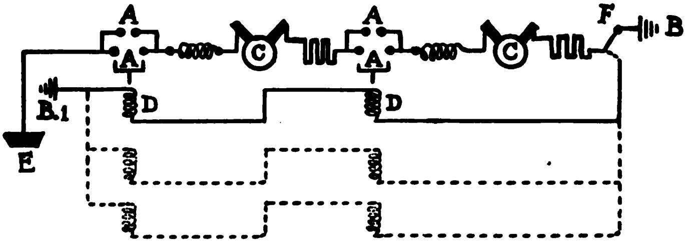


Fig. 43. Diagram Illustrating Principle of System.

Fig. 43, which represents a control circuit for two motors, affords a clear preliminary explanation of its action.

The trolley or third rail shoe is represented in the diagram by the letter E, and the motors, with their armatures, fields and resistances, by CC. The ground connections are B and B-1. A circuit is established between E and B by closing the contacts AA, at the same time setting the two-way switch F to connect the motor circuit with B-1. This being done, the motors are started and the current flows from them through the contactor solenoids, DD, energizing them, and causing the main contacts AA to close. The contacts CC may now be opened and not break a circuit, since they are duplicated by AA. Obversely, the current flowing through the solenoids D would be diverted to ground at B, the magnets would become de-energized and the contacts AA would open, should the switch F have been moved to B.

Fig. 43 shows the dotted lines containing as many solenoids as are required for the control system and explains how the circuit FDDB can be paralleled by others. These solenoids are brought in or out of the circuit at the proper time by the switch F, which is constructed for that purpose.

The system consists of two master controllers, located one at each end of the car. Under the cars are suspended series-parallel, and resistance contactors, and reversers.

A diagram of the wiring and connections for a two-motor equipment is shown in Fig. 44 and also the development of the master controller, which consists of three distinct parts: the contactor barrel, switch barrel and reversing barrel.

The wiring of the system of control is indicated by the light lines, and the path of the current driving the motors by the heavy lines. The cut-out switches are not shown, to avoid confusion in a complex diagram.

The main operating handle moves the switch barrel, and contactor barrel of the master controller, which are in the same vertical plane. The switch barrel travels through an arc shown on the diagram, and its movement through this arc is independent of the contactor barrel; but after the switch barrel has turned through this arc, the contactor barrel turns with it, and they then move

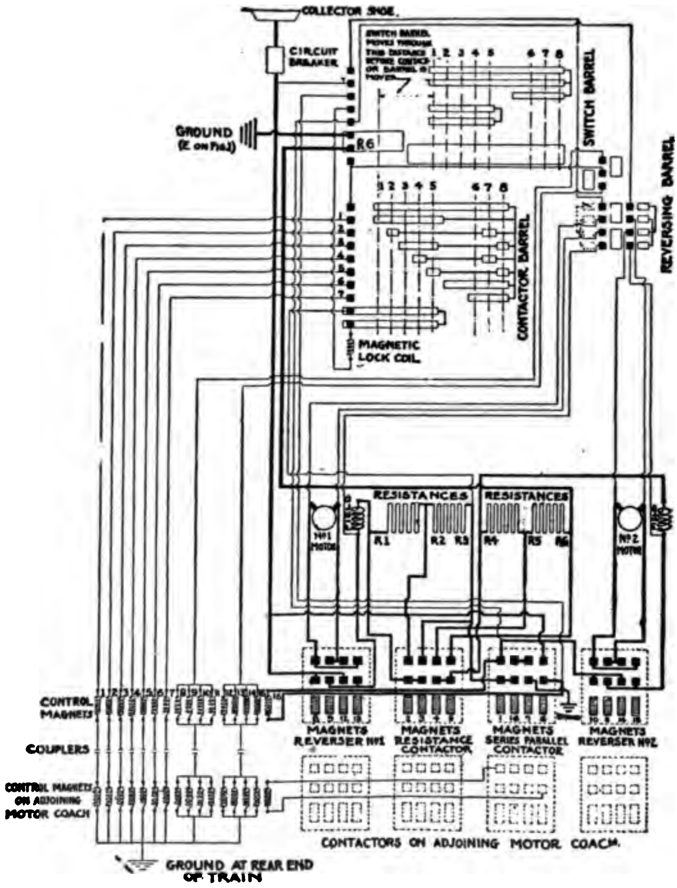


Fig. 44. Schematic Diagram of Controller Circuits

in unison until reaching full speed position. To facilitate tracing the various connections, the eight notches on the controller are indicated and numbered on the diagram. The reverser barrel is in two parts and is provided with a drum for switching in either the forward or reverse set of contactors, and a drum for reversing the control circuit through both motors. The three positions of the reverser barrel are: "Forward," "Off," "Reverse." To facilitate comparison, references are made in the diagram, Fig. 44, to points in Fig. 43. The controller is at the off position and the ground sector of the switch barrel connects the negative end of the motor circuit (R-6) to ground E (Fig. 43), whereby the open contactors are de-energized and the motor circuit has been interrupted. The first controller movement is made at the reversing switch in order to start up. The switch is pushed from "off" position to "forward" or "reverse," as the case may be. The control circuit through the motors to ground, and the ground sector of the master controller is completed by this movement, but no current is admitted to the circuit. By this same movement the controller handle is released, and notching up can begin, as the reversing controller and handles are mechanically interlocked. To obviate notching up too fast, a mechanical controller handle regulator is provided. The ground B is then disconnected by the ground sector, and the solenoid sector connects the end of R-6 with the control system at the same time that the contactor barrel begins to move with the switch barrel and pass into the first notch, and the trolley rings close a control circuit which can be readily traced on the diagram. The lower reversing barrel, the motors with their fields, resistances, and reverser solenoids 8, 9, 10 and 11 and paralleling solenoid

1 are all included in the circuit. These are all in series with each other and with all the other control sections on the train to B-1, the final ground shown in Fig. 43, and which is always at the rear end of the train. The motors then are started up in series with all resistance in circuit by the closing of reverser contactors 8, 9, 10, 11 and series parallel contactor 1. The resistance is cut out of the series connection of the motors by the next four notches, and that is the extent of their action. The interval between notch 5 and notch 6 breaks the circuit of the resistance solenoids 2, 3, 4, 5 and series solenoid 1, when the transition from series to parallel is made. The resistance contactors close again with solenoid 6; meantime the trolley ring, and reverser contactor solenoid circuits are maintained.

The paralleling contactors 6, 7 and 16 are closed by means of the control circuit notch 6, thereby placing the motors in parallel with the resistance in circuit. When notches 7 and 8 cut out the resistance, full speed is attained. A single sweep of the handle to the "off" position will shut off, and in making this movement the switch barrel turns back independently of the contactor barrel, which remains at full parallel until the ground sector of the switch barrel diverts the motor current to ground B. This causes all the contactors to drop off and break the motor circuits throughout the train. The two barrels then return together to the position as shown in Fig. 44.

The master controller (Fig. 45) does not break any current, is of small size and needs no magnetic blow-out. There is a magnetic lock in the base of the controller, consisting of a small coil in series with the contactor solenoid 1. This magnetic lock determines the series connection of the motors, and when energized it releases a catch and allows the motorman to notch up to full-series. The controller cannot be notched if the series contactor is not pulled up, as it remains securely locked.

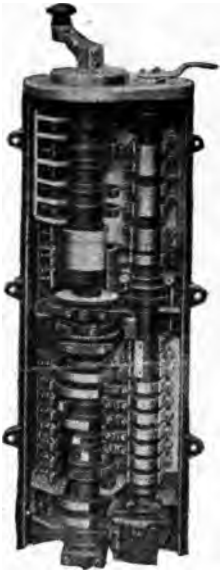


Fig. 45. Master Controller.

The ground connection for the contactor circuit, and that for the current diverted from the circuit are at opposite ends of the train; the former at the rear end, as it is here that the return current is allowed to go to the ground after passing through all the contactor solenoids in the motor cars on the train.

When it is required to de-energize the solenoids, the other ground to which this current is diverted is at the front of the train. The entire system must be paralleled at the front, and rear master controllers to permit control from either end of the train. Concisely stating the operation of this system: The negative current from the motors of the leading motor car, the master controller of which is being operated, supplies the control system of the entire train in which every solenoid is in series. To illustrate: Solenoid 1 is in series with solenoid 1 of each car until the circuit goes to ground B, at the rear end of the last car. The same applies to all the rest, as they constitute separate circuits, all numbered according to the contactor which they actuate. This current from the leading car operates the contactors of every other car in the train and each discharges its negative current to ground at B-1; for their master controllers are in the position shown in Fig. 43 and the circuit is complete through the ground sector of each master controller.

Nine train wires grounded at each end of the train are required by this control system. At the ends of coaches special provision is made to carry the leads and special plugs, and at both ends of each car sockets are used with jumpers.

No shoe cable or busline is required through the train.

REPAIRS.

- Motors. Access to the motor should be provided by a trap door in the floor of the car through which the motor and armature can be easily inspected. In mounting repaired motors, great care should be taken in fitting the axle keys in both the axle and axle gears, otherwise the gears may work loose. All bolts should be tight, and where cotter pins are used, care should be taken to see that they are opened far enough to prevent their slipping out.

Motors should be regularly examined by competent inspectors to keep them in proper condition. The plan of inspecting equipments every night, immediately after the arrival of the car in the barn, or as soon after the arrival as possible, is followed with excellent results. The car should be placed over a pit for this examination, or if there is no pit, the trap or floor doors in the car should be opened, and the motors examined from above. The armature bearings should be carefully examined, and if their temperature is excessive and the grease in the cups has melted out, the bearing caps should be removed and the bearings examined. If the metal has been burned or run, sufficient to cause injury, the bearings should be replaced by new ones. The axle bearings should also be examined, and also the armatures, and commutator brushes. The controller, circuit breaker, car wiring, and in fact the complete equipment, should be carefully examined.

In the operation of motors the question of lubrication is one of the most important. The best lubricant depends on the conditions of operation, and type of bearing. The oil cellars in the armature bearing should be kept filled. A good quality of oil and grease should be used. In winter a somewhat lighter grade of grease should be used than in summer. The oil wicks should be kept in good shape. Care should be taken not to allow the felt to wear off, and the springs to come in contact with the journal. If this precaution is neglected, the journal will be grooved in a short time. The bearings must receive careful attention. Many armatures are ruined by being run in bearings which are worn to such an extent as to allow the armature to strike the pole pieces. The clearance between the pole pieces and the armature should be frequently measured, and when clearance is found insufficient the proper adjustment should be made at repair shops.

In handling armatures, care must be taken to avoid mechanical injury, and aberration of the insulating materials. When armatures are set aside after being repaired, waiting to be put into service, a dry location must be selected, and the armatures protected from dust and mechanical injury.

In the repairing of motors, particular attention should be given to loose nuts, bolts, cotters, or other parts. If such parts drop down into the motor frame, they are very likely to give serious trouble. If bolts become loose, the excessive strains caused thereby may result in breakage of parts.

The commutator should be examined by the motorman occasionally when the car is under full headway, if practicable. If the brush tension is not right and there is flashing, the brush holders should be properly adjusted temporarily and the repairs made on reaching barn.

Commutators should be kept clean, and rough commutators should be turned, and every attempt made to keep them in a true and smooth condition. Ridges and dirt on the commutator result in unnecessary destruction of the apparatus.

Drain plugs in the bottom of the magnet frame should be left out in order to prevent an accumulation of water which may ground the field coils.

BRUSHES. In making repairs where the trouble is due to short brushes, and new brushes are substituted for old ones it is important to use brushes of the proper size and length. If brushes are allowed to wear too short, the brush-holders may bear on the commutator. A list of brushes for use with standard General Electric railway motors is given below.

Motor.	Length.	Breadth.	Thickness	Number of Brushes
GE- 800	$2\frac{7}{16}$	$2\frac{1}{4}$	$\frac{1}{2}$	2
GE-1200	$2\frac{7}{16}$	$2\frac{1}{4}$	$\frac{1}{2}$	4
GE-1000	$2\frac{1}{4}$	$1\frac{3}{8}$	$\frac{1}{2}$	4
	$2\frac{1}{4}$	$2\frac{3}{4}$	$\frac{1}{2}$	2
GE-2000	$2\frac{1}{4}$	$1\frac{3}{4}$	$\frac{5}{8}$	6
GE- 50	$2\frac{7}{16}$	$2\frac{1}{4}$	$\frac{1}{2}$	4
GE- 51	$2\frac{1}{2}$	2	$\frac{5}{8}$	4
GE- 52	$2\frac{1}{4}$	$1\frac{1}{4}$	$\frac{1}{2}$	4
	$2\frac{1}{4}$	$2\frac{1}{2}$	$\frac{1}{2}$	2
GE- 53	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{5}{8}$	4
GE- 54	$2\frac{1}{4}$	3	$\frac{3}{8}$	2
GE- 55	2	$1\frac{3}{4}$	$\frac{9}{16}$	8
GE- 57	$2\frac{1}{4}$	$1\frac{3}{4}$	$\frac{5}{8}$	4
GE- 58	$2\frac{1}{4}$	$1\frac{3}{8}$	$\frac{1}{2}$	4
	$2\frac{1}{4}$	$2\frac{3}{4}$	$\frac{1}{2}$	2
GE- 60	$2\frac{1}{4}$	$1\frac{1}{4}$	$\frac{1}{2}$	4
GE- 66	$2\frac{1}{4}$	$3\frac{1}{4}$	$\frac{9}{16}$	4
GE- 67 (4-turn)	$2\frac{1}{4}$	$3\frac{3}{8}$	$\frac{3}{8}$	2
GE- 67 (3-turn)	$2\frac{1}{4}$	$3\frac{3}{8}$	$\frac{1}{2}$	2
GE- 73	$2\frac{1}{4}$	$2\frac{1}{2}$	$\frac{1}{2}$	4

Controllers. In the standard car equipment one controller is placed on each platform on the side opposite the brake handle. The exact position depends somewhat on the location of the sills sustaining the platform. The feet of the controller are designed to allow a slight rocking with the spring of the dasher and a dowel pin is to be placed in each foot, the bottom end projecting into a ¾″ hole bored into the car platform. An adjustable angle iron is furnished to secure the controller to the dash rail. A wire guard is also furnished for protecting the cables which pass into the controller. When controllers leave the repair shop and are again ready to be put in service, care should be taken to blow out all dust with bellows or air blast. The controller frames are grounded by means of inside connections.

Controllers should be examined and cleaned at least once a week, the bearings being oiled whenever necessary.

Large controllers subject to heavy service require more frequent examination and repairing. Particular attention should be paid to keeping the fingers and segment tips in good condition. The segments should be wiped clean, and if very rough, sandpapered or filed, a very small amount of vaseline being finally applied.

Contact fingers should be adjusted so as to allow a drop when leaving the segments of not less than 1/32″ nor more than 3/32″.

All screws and check nuts should be examined at intervals and tightened when necessary. Care should be taken to blow out all dust with bellows, or air blast before applying oil or vaseline.

In another part of this work the various standard controllers have been referred to in connection with their several characteristics; but for the better information of the student the following table showing some of the principal types of series parallel controllers of the G. E. Co. is introduced:

TITLE	CAPACITY	CONTROLLING POINTS.	REMARKS
K	Two 35 H.P. Motors.	4 Series. 3 Parallel.	For motors using loop or shunted field.
K-2	Two 35 H.P. Motors.	5 Series. 4 Parallel.	For motors using loop or shunted field.
K-4	Four 30 H.P. Motors.	5 Series. 4 Parallel.	For motors using loop or shunted field.
K-6	Two 80 H.P. Motors or Four 40 H.P. Motors.	6 Series. 5 Parallel.	Connection board so arranged that controller may be used for two or four motors on grounded or metallic circuit.
K-8	Two 50 H.P. Motors.	5 Series. 4 Parallel.	Similar to K-11 but arranged for metallic circuit system.
K-9	Two 35 H.P. Motors.	5 Series. 4 Parallel.	Similar to K-8 but has connecting wires and blow-out coil of smaller capacity.
K-10	Two 35 H.P. Motors.	5 Series. 4 Parallel.	
K-11	Two 50 H.P. Motors.	5 Series. 4 Parallel.	Similar to K-10 but has connecting wires and blow-out coil of larger capacity.
K-12	Four 30 H.P. Motors.	5 Series. 4 Parallel.	Similar to K-11 but has reversing switch arranged for four motors.
K-13	Two 125 H.P. Motors.	7 Series. 6 Parallel.	
K-14	Four 60 H.P. Motors.	7 Series. 6 Parallel.	
L-2	Two 175 H.P. Motors.	4 Series. 4 Parallel.	
L-3	Four 150 H.P. Motors.	8 Series. 7 Parallel.	
L-4	Four 100 H.P. Motors.	4 Series. 4 Parallel.	Similar to L-2 but with additional reversing switch parts for four motors.
L-7	Four 200 H.P. Motors.	9 Series. 6 Parallel.	

Rheostats. In repairing, and replacing rheostats they should be protected from moisture as much as possible without interfering with the free circulation of air, being so located that water and mud from the wheels will not be thrown into them. Ample space should be provided between the top of the rheostats, and the floor of the car, the supporting feet generally being sufficient. Four ½″ bolts should be used for securing each rheostat to the car body. In some instances special planks should be first attached to the car sills for supporting them.

The Trolley. Trolley poles and bases requiring repairs should not be replaced on trolley board, on roof of car until the board has been examined and found to be, or put in good order, so that it will afford a suitable support for the trolley base.

Trolley stands should be examined occasionally and kept in condition to permit of free turning by sufficient lubrication.

Connection to the trolley stand should be examined at intervals.

Trolley wheels showing signs of wear should be replaced before they begin to cause flashing and consequent injury to overhead line.

Circuit Breakers. The circuit breakers should be located in the vestibules of the cars, at the right of the motorman and within easy reach. They may be enclosed in a box to deaden the noise. Sufficient space should be allowed between the blow-out chute, and the woodwork of the car to avoid discoloring the paint. Circuit breakers should be connected in parallel, so that the car can be operated with either controller with one breaker setting.

The working parts should be kept clean, and the blow-out chute free from carbon deposits. The contacts must be kept smooth and in good condition, and occasionally lubricated with a small amount of vaseline.

Car Wiring and Cables. Fig. 46 shows the car wiring for two K-10 controllers with two motors. Fig. 47 shows car wiring for four GE-67 motors and two K-14 controllers. In making repairs of the power wiring of a car, the important points are:

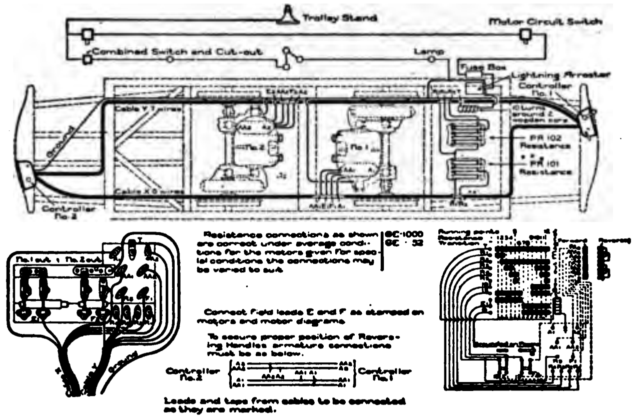

Trolley Stand
Motor Circuit Switch
Combined Switch and Cut-out
Lamp
Fuse Box
Lightning Arrester
Controller No. 1
10 turns around 2 wooden core
Cable Y 7 wires
ground
No. 2
No. 1
PR 102 Resistance
PR 101 Resistance
Cable X 8 wires
Controller No. 2
No. 1 cut. 1 No. 2 cut
Resistance connections as shown are correct under average conditions for the motors given for special conditions the connections may be varied to suit.
GE-1000
GE · 52
Running points
Resistance
Transition
Forward
Reverse
Connect field leads E and F as stamped on motors and motor diagrams
To secure proper position of Reversing Handles armature connections must be as below.
Controller No. 2
Controller No. 1
Leads and tags from cables to be connected as they are marked.

Fig. 46. Car Wiring for K-10 Controllers with Two Motors.

1st. Protect all wires underneath or inside the car from mechanical injury through strains due to racking of the car body, or from chafing, with motor frames, trucks, wheels, brake rigging, rheostat frames or other parts.

2d. Locate the cables and wires so that the heat from rheostats and heaters will not seriously affect the insulation.

3d. Avoid placing wires of extreme difference of potential in close proximity.

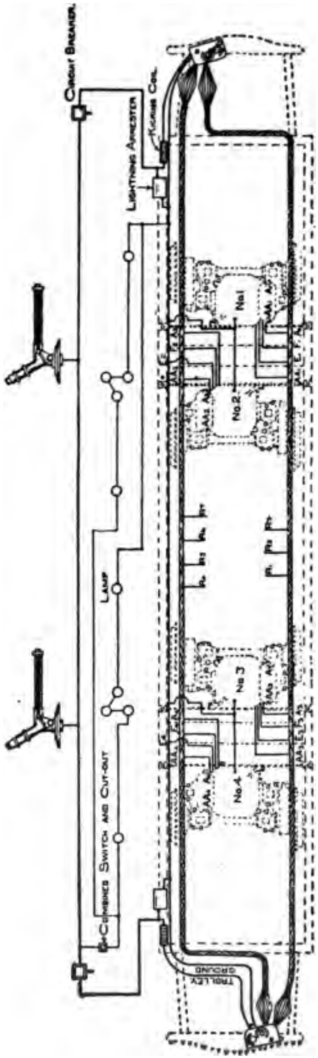


Fig. 47. Car Wiring for Four GE-67 Motors and Two K-14 Controllers.

4th. Solder all permanent taps and splices and thoroughly tape them.

5th. Securely support cables and wires so as to minimize vibration.

6th. Tighten well all set screw or clamp connections at controllers, rheostats, fuses, circuit breakers and other points.

In general, the cables should be located in dry out-of-the-way positions. It is sometimes preferable to run them in a boxed compartment carried along the car sills from end to end of the car. On open cars the cables should be located under the car bodies and platforms, as near the center line of the car as possible. They should pass around bolsters, so that water and mud thrown by the wheels will not reach them. Care should be taken on all double-truck cars to see that the cables are so placed that the wheels will not cut them in rounding sharp corners. In closed cars with seats running lengthwise, cables should be carried under the seats and supported on brackets, or with leather cleats to keep them off the floor of the car. The cables should be located so as not to interfere with the car heaters and it is preferable to run the cables under, rather than over the heaters. All taps from the cables to the motors should be as short as possible with sufficient slack to prevent strains and on double-truck equipment a coiled metal armor should preferably be used. All connections between these taps, and the motor leads should be thoroughly made. A common point of weakness is in the method of taking the field and armature leads from the motors to their point of attachment on the car body.

Fig. 48 shows the standard car roof wiring for circuit breakers. The details of a car wiring arrangement may naturally vary with different conditions. In replacing wires nothing but stranded wires should be used, so as to prevent breaking of the wires and consequent arcing. The main wire from the trolley should be brought

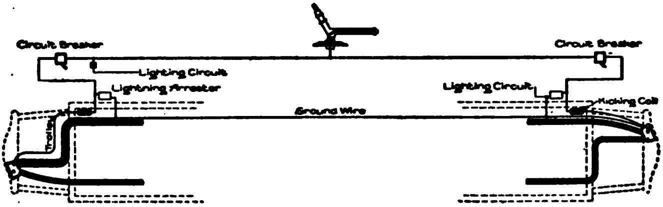


Fig. 48. Standard Car Roof Wiring for Circuit Breakers.

into a protected place inside of the roof, and so located that water will not follow the wire. All taps and joints after being well soldered, should be covered with splicing compound and adhesive tape. Wires should not be placed where they will be injured by car doors.

REPAIR CATECHISM.

Q. 1. What is the function of a fuse?

A. To break the circuit when an overload of current is maintained.

Q. 2. In what manner is an overload of current at motor terminals prevented by a fuse?

A. By melting and thus breaking the circuit.

Q. 3. Why is a narrow space left between the box and the fuse?

A. To counteract the rise in temperature caused by an overload of current, by permitting a current of air to pass around the fuse.

Q. 4. Is the equipment in danger by the use of fuse heavier than the regular one?

A. Yes, the fuse must be adapted to the current which it is intended it should carry, and beyond which it would melt. If the fuse were of a heavier kind and greater capacity it would carry a greater amount of current than the equipment would stand with safety.

To illustrate this, let me assume that a metallic cylinder can withstand a pressure of 100 pounds of gas to the square inch, and that it is provided with a safety valve, which is set to blow off at 75 pounds. In such a case it would be impossible for the cylinder to explode, as the gas would escape before the pressure reached the point where the cylinder could withstand; but if the valve were set at 150 pounds, and the pressure of the gas exceeded 100 pounds, the cylinder would be liable to explode.

Q. 5. Explain an overload of current.

A. An overload of current is an amount which exceeds the carrying capacity of a fuse in circuit. When there is a heavier current flowing in the circuit, than the full load rating of the motors.

Q. 6. What causes an overload of current?

A. Grounds or short circuits in the wiring of motors, which produces a small amount of resistance, and then the load rises; for instance, the pressure on a line is 500 volts, and motor becomes short circuited with which ground little resistance is caused. Now, two ohms being the amount of resistance, the amount of current passing this circuit would equal 500 volts divided by two ohms. This permits 250 amp. of current to pass, and for a 150 amp. fuse would be an overload of 100 amp. above the carrying capacity of the fuse. Overloads are also caused sometimes by lightning striking the line, heavily charging it; and also by improper use of the controller—reversing or feeding too fast; notching up the controller too fast, or trouble in one of the motors, or a ground in the wiring.

Q. 7. Does the fuse represent the weakest point of a circuit?

A. Yes; it should.

Q. 8. Why is it necessary to create this weak point?

A. In order to break the circuit when necessary where the fuse is located, so as to protect the equipment.

Q. 9. Where in the circuit is the fuse usually located?

A. Between the lightning arrester or controller, and the second main motor switch, just after the circuit comes from the trolley lead.

Q. 10. Of what is a fuse composed?

A. Of a composition of lead and tin, usually. It may also be composed of a very fine copper wire.

Q. 11. How is the carrying capacity of a fuse known?

A. The carrying capacity of a fuse is equal to that amount of current which will pass through it, without causing it to melt, and the carrying capacity is expressed in amperes, which is stamped on one of the copper terminals of the fuse.

Q. 12. What is the proper method of inserting a fuse?

A. The composition part should be bent in a manner to leave an air space between the face of the fuse and box; the fuse terminals should be securely fastened to the binding part with thumbscrews. Be sure that the circuit is opened by a switch, and that the trolley is off.

Q. 13. Will it cause heating of coils to run on resistance points? and if so, why?

A. Yes, it would cause heating of resistance coils, as the currents would be retarded by the resistance of the coils. On resistance points all the current that the motors are taking is passing through the resistances, and as they are not built to carry this current they will become very hot.

Q. 14. What is the reason that resistance is used in motor circuits?

A. To overcome the rush of current to motor terminals, causing too sudden movement of armatures. If the full voltage were thrown on before motors were up to speed the current taken from the line would be excessive and would probably flash the motor over.

Q. 15. When is resistance sometimes termed exterior resistance?

A. When the resistance is in connection with the motor circuit.

Q. 16. Are resistance coils sometimes called rheostats, or diverter coils?

A. Yes.

Q. 17. Describe the component parts of a resistance coil for street railway motors?

A. The resistance is usually composed of long strips of iron ribbon at the present time, having supplanted resistance coils which were formerly composed of German silver wire, the use of which has been practically abandoned by reason of the expense, and because wrought or cast iron answers equally well for all practical purposes.

Q. 18. How are resistance coils constructed?

A. They are usually made in two forms, the cylindrical and panel form. The cylindrical, as its name indicates, is in the form of a cylinder, and the layers of the coil are separated with asbestos or mica insulation. In the panel form the coils are placed in panels or layers, with asbestos between each layer.

Q. 19. What is the purpose of asbestos or mica in the construction of resistance coils?

A. To secure the full resistance of the coils, and to prevent them from becoming short-circuited. These two materials are capable of withstanding a very high degree of temperature, and they are also insulaters of great efficiency.

Q. 20. What are the safe running points of a GE, K or K1 controller?

A. 3, 4, 6, 7.

Q. 21. What are the resistance points of a GE, K or K1 controller?

A. 1, 2 and 5.

Q. 22. What are the safe running points on a GE, K-2 controller?

A. 4, 5, 8 and 9.

Q. 23. What are the resistance points on a GE K-2 controller?

A. 1, 2, 3, 6 and 7.

Q. 24. What are the safe running points on a G. E. K-10, K-11 or K-12 controller? and what are the resistance points?

A. Running points 5 and 9; resistance points 1, 2, 3, 4, 6, 7 and 8.

Q. 25. How are the different points distinguished from each other?

A. The long bars on dial plates indicate the safe running points and the short bars indicate the resistance points.

Q. 26. What are the safe running points on a Westinghouse 28-A controller?

A. 4 and 7, marked respectively one-half speed and full speed.

Q. 27. What are the resistance points on a Westinghouse 28-A controller?

A. 1, 2, 3, 5 and 6.

Q. 28. Where, relative to the end of the car, is motor No. 1 located?

A. Nearest the fuse box.

Q. 29. Where is motor No. 2 located?

A. Farthest away from the fuse box.

Q. 30. In a G. E. controller, how is motor No. 1 cut out? How is motor No. 2 cut out?

A. Motor No. 1 is cut out by raising the left hand switch in the controller, and motor No. 2 is cut out by raising the right hand switch. By throwing cut-out switch in bottom of controller.

Q. 31. In a Westinghouse No. 28-A controller, how is motor No. 1 cut out? How is motor No. 2 cut out?

A. Motor No. 1 is cut out by placing the handle of the No. 1 cut-out plug—which is the bottom plug—in a vertical position in both controllers. Motor No. 2 is cut out by placing the handle of the No. 2 cut-out plug —which is the top plug—in a vertical position in the controller which is at the time being operated.

Q. 32. Before cutting out a motor, what precaution should be taken to avoid damage?

A. When cutting out a motor or inserting a fuse the over-head switch, or circuit breaker must be thrown off.

Q. 33. Is it injurious to motors to operate a car with the brakes partly set, and the power on? and if so, why?

A. Yes; because the armatures and field coils become heated, and the insulation is thereby destroyed.

Q. 34. What effect has heating upon the armature and field coil insulation?

A. It causes them to become carbonized and brittle.

Q. 35. What results when the insulation of an armature or field coil becomes carbonized?

A. The layers of the coils of wire form metallic connections which cause short circuit or ground. The insulation cracks and the armature or field becomes grounded.

Q. 36. Is it proper to run a car through water at an excessive rate of speed with the power on? and if not, why?

A. No; because short circuits in field and resistance coils, and other parts of the motor are liable to occur if run at high speed. On open motors the water would be liable to be thrown into motors.

Q. 37. Describe a controller interlocking device?

A. It is a contrivance which prevents the controlling cylinder from being operated when reverse handle is in the center; it also prevents the reverse cylinder from being thrown in either direction when controlling cylinder is put in circuit.

Q. 38. What systems use this device?

A. Westinghouse and General Electric Co.

Q. 39. If a car equipped with a G. E. controller has a grounded controlling cylinder, how should it be operated?

A. It cannot be operated if the controller frame is grounded, as it would surely be.

Q. 40. If a car equipped with a G. E. controller has entire resistance in circuit, motors in series, and controller cylinder grounded, how should it be operated?

A. It cannot be operated if the controller frame is grounded, as it would surely be.

Q. 41. Where in a G. E. controller is the trolley wiper located?

A. On top of the wiper board. First from the top.

Q. 42. Where in a Westinghouse 23-A controller is the trolley wiper located?

A. On top of the controller.

Q. 43. If a car equipped with a G. E. controller has a grounded reverse cylinder, how should it be operated?

A. After throwing the reverse cylinder completely out of connection, the reverse contact wiper should be wired in pairs for a forward movement of the car, and the reverse contact wipers should be cross connected for a backward movement.

Q. 44. How are reverse contact wipers connected in pairs?

A. By connecting with jumpers from one to the other, the bottom contact wiper to the second contact wiper up on the reverse switch. This will leave remaining six wipers, which should be similarly connected in pairs. When this is done the third and fourth wipers will be connected together, which, with No. 1 and No. 2 wipers, compose the connections of motor No. 1. Then the fifth and sixth wipers and also the seventh and eighth will be connected which compose the connection of motor No. 2.

Q. 45. What will be the effect of a blow-out magnet coil becoming grounded, and how could a car be operated under such conditions?

A. The fuse would be blown in circuit, when both circuit breakers or overhead switches are thrown on to close circuit and controller handle is at off position. To run the car it would be necessary to disconnect the positive and negative wires of the blow-out magnet coil and connecting them together, thereby removing the blow-out magnet coil from the circuit.

Q. 46. Describe a blow-out magnet coil, and explain its function?

A. It is a contrivance composed of insulated copper ribbon or wire, and, wound on a core, it excites the pole piece, thereby creating magnetic lines of force which break the arc when controller is being thrown to the off position. A blow-out magnet is a magnet that is used to pass magnetic flux through a space where an arc has been formed. By this means the arc is blown out at right angles to the line of the flux.

Q. 47. How would a forward direction in the car be obtained by connecting contact wipers in pairs, and how would backward direction be obtained?

A. By making the connection as above the car will go ahead from the end of the car from which the connections are made, and the backward motion would be obtained by cross-connecting the reverse contact wipers.

Q. 48. How are cross connections made?

A. By connecting together the bottom reverse and third wiper, and the second and fourth wipers for connections of motor No. 1. Then connect together 5th and 7th wipers, and 6th and 8th wipers for connections of motor No. 2.

Q. 49. Why is it necessary to break an arc when throwing controller to an off position? Is there any other means employed to minimize the arc at contact wiper points?

A. An arc held in the controller causes short circuits or grounds, and it is therefore necessary to break the arc by means of blow-out magnet coils, or by arc deflectors, which are also used for that purpose. These deflectors are located between contact wipers, opposing a barrier to the arc. Circuits are sometimes broken by contactors under the car.

Q. 50. What injurious results attend the too abrupt application of power?

A. Short circuits in brush holder yokes and armature windings are liable to occur from too suddenly allowing full force of current to flow to the motor terminals, and short circuits or grounds may also be caused in the controller by the backing up of the current. A too sudden application of power causes severe strains to mechanical parts of the equipment, even exposing gears and pinions to the liability of being stripped.

Q. 51. Explain an emergency stop with controller?

A. A stop made without the use of the brakes or line power, and it is effected in the following manner: The overhead switch is thrown to the off position; the reverse handle is thrown in the direction contrary to that in which the car is traveling; the controller cylinder handle is thrown to the last parallel position. The effect of this is to cause a generation of current by the motors themselves. The motors being held in opposite polarity, the stronger motor becomes a generator, and drives the weaker one in the contrary direction as a motor. An emergency stop with power should be made by throwing the reverse handle, and then bringing the controller up to the first point. As the car begins to slow down the controller can then be notched up one or two points.

Q. 52. When motors are of the same type and equal horse power, why is one motor sometimes referred to as being stronger than the other?

A. The relative strength of their magnetic fields determines which is the stronger or weaker of the two motors.

Q. 53. What conditions warrant the execution of an emergency stop?

A. Failure of line or brake power, and when an accident would result unless the motorman resorted to an emergency stop. To avoid a collision with another car or to avoid running over some person or vehicle on the track.

Q. 54. If the reverse switches were set for a forward motion with both controllers, and the power was applied from one end, what would be the effect?

A. With either controller the fuse would be blown in circuit on the series positions, and the car could not be moved in a forward direction.

Q. 55. If the reverse switch on controller No. 1 were set for forward motion, and on No. 2 for backward motion, what would be the effect?

A. The armatures would be short circuited, and the car would not move.

Q. 56. Explain the series positions?

A. When two motors are connected in series their positions in the circuit are such that the current flowing through motor No. 1 must pass through motor No. 2 before the circuit is completed.

Q. 57. Explain the parallel or multiple positions?

A. Each motor connected in parallel or multiple is in a circuit of its own independent of the other motor.

Q. 58. What is liable to occur by throwing the reverse switch with the power on, as some types of controllers will allow?

A. Flashing the motors over. It is liable to cause short circuit in armature coils; a short circuit is produced in the controller and the fuse in circuit is melted.

Q. 59. In electric railroading, what is the ordinary voltage on line?

A. 550 volts.

Q. 60. What is the positive side of a circuit? What is the negative side of a circuit?

A. The positive or plus side is that side of a circuit through which the circuit flows in to it. The negative or minus side of a circuit is the side by which the current leaves it. The positive side of the circuit is the trolley, and the negative the rail in electric railroading.

Q. 61. Describe the pole piece of a motor? Are the iron magnets inside of the motor shell temporary, or permanent magnets? If they are temporary, why? and when do they cease to act as magnets?

A. The iron magnets inside the shell are called the motor pieces, and they are temporary, being magnetized —or becoming magnets—when energized by the surrounding field coils, and when the power ceases they cease to be magnets.

Q. 62. How many pole pieces are there usually in each motor?

A. Four.

Q. 63. By what names are they known, to distinguish one from the other?

A. North pole, and south pole.

Q. 64. If a motor has four pole pieces, why are there two of them north poles and two of them south poles?

A. To permit the attraction and repulsion of an armature the magnetic field must be evenly balanced in polarity, and therefore the number of negative and positive poles must be equal.

Q. 65. How does the attraction, and repulsion of an armature affect the movement of a car?

A. It causes the revolution of the armature, which in turn causes the propulsion of the car, the pinion on the armature shaft engaging the gear on the truck, and causing it to revolve, which turns the wheels.

Q. 66. What is gear ratio? Explain it?

A. The relation of pinion to gear as to the relative revolutions of each, for every revolution of the armature. For instance: If a pinion has a certain number of teeth—say 15—and the gear has 60, the pinion would revolve four times for every revolution of the gear wheel, and hence the gear ratio would be expressed as 4 to 1.

The gear ratio is the ratio of the armature revolution to the revolutions of the car wheels.

Q. 67. What are the gear ratios of the several railway motors?

A. About three to one and five to one.

Q. 68. How are gears and pinions secured to truck axle, and armature shaft?

A. Gears are either pressed on the axle, or when made in two halves bolted on. They are held from turning by means of a key.

Pinions are usually put on a taper fit and are held from turning by a key. They are kept on by means of a nut on the end of the shaft. This nut is kept from turning by means of a lock washer.

Q. 69. When a pinion is placed on an armature shaft by means of expansion, how is this expansion obtained, and how is its contraction effected?

A. It is expanded by heating, and contracts when cooled.

Q. 70. What is the object of placing circuit breakers in the overhead trolley wire along the line at intervals?

A. So that the trolley can be sectionalized in case of trouble on the line, and not tie up the whole system.

Q. 71. What injurious results may follow running over circuit breakers with the power on?

A. An arc might hold that would burn the wire off.

Q. 72. What is an electric track switch, and how is it constructed, connected and operated?

A. It is a contrivance placed below the street level between the two track rails and serves to close or open switches for certain directions, and consists of an electro-magnet, the armature having an inverted pendulum connected to it, with a conically shaped point.

There is a recess in a slide bar connected with switch-tongue point, and the conical part of the pendulum rests in this recess when the switch is operated.

The connection is made by attaching one end of the wire leading to the electric magnet coil to the insulated rails, and the other end to the electro-magnet coil at the positive binding post. The return wire of the track and the negative side of the coil are connected by a wire making a complete connection. The trucks must stand on insulated track, in order that the magnet may be operated, and which is done by the return circuit of the car motor. When the trucks pass over the insulated section of track, and the switch is set for the proper direction of the car, they form a connection with the main return wire, and the power must always be off while passing over the insulated section to prevent the switch from being thrown.

Q. 73. In what way is it dangerous to operate a car at an excessive rate of speed, over facing point switches?

A. The first pair of wheels might take the switch all right, and the others split it and derail the car.

Q. 74. Why is it dangerous to back a car without first turning the trolley pole?

A. The trolley pole might catch and pull the line down.

Q. 75. Is it safe for cars to pass one another on a curve, or for a car to pass a standing car on an opposite track?

A. It depends upon the layout of the curve. It is dangerous for one car to pass another car that is unloading passengers.

Q. 76. What should be done to a car in order to leave it in a safe condition when it is turned into the car barns after a day's work?

A. Pull the trolley down and take the controller handles off.

Q. 77. What should be done when the power leaves the line?

A. Throw the controller handle to the off position.

Q. 78. What should be done when the power is again restored to the line, after it has been off, whereby the car was unable to move?

A. The cars should be started on the line in alternating order, so as not to load the line too heavily all at once, as this might cause a fuse to be blown, or a circuit breaker thrown out at station. A practical way to start the cars moving on the line is to make a rule that under such circumstances all the cars of even number start first and then the cars of odd numbers.

Q. 79. Where should the trouble be looked for when the controller cylinder is thrown to the first position, and the motors do not act with circuit?

A. This trouble may arise from any one of several causes. Open circuit car wiring; a broken or short carbon burst; trolley wheel resting on line circuit breaker, or car standing on dead or dirty rail.

Q. 80. What should be done to a car on a dead or dirty rail?

A. Use a switch bar or some conducting material to make contact between the wheels and the rails.

Q. 81. What does it signify when the power handle is thrown to the first position and the car does not move, but when throwing it off a flash in the controller is observed?

A. Either that the brakes are on, or that there is a ground between the resistance and motors.

Q. 82. Why are cars equipped with M. M. switch or circuit breakers on each end of the car?

A. So that in case the controller fails to break the circuit the switch can be opened.

Q. 83. How should a car be operated when going down a grade?

A. Speed should be kept low enough so that the car is always under control.

Q. 84. How should a car be operated in a fog or through dark streets?

A. At slow speed and under full control.

Q. 85. Should the motors be built up quickly when the rails are slippery?

A. No.

Q. 86. What would be the effect of operating a car with a hot journal bearing?

A. It would anneal the journal and spoil the axle.

Q. 87. When sleet and ice prevent contact of the trolley wheel with the wire, what should be done?

A. Use sleet wheels.

Q. 88. When an arc is maintained after a fuse is blown, what should be done?

A. Pull the trolley down.

Q. 89. What causes sprung axles and what is the proper course to pursue when such irregularity occurs?

A. Sprung axles are caused usually by derailments through carelessness; by defective tracks, and wheels dropping into recesses of worn castings. When a sprung axle is discovered let the wheel turn till it best fits gauge of track and make it secure to side of truck so it cannot turn. Cut motor out which operates the defective wheels so they will slide to car barn.

Q. 90. When the car has a sprung axle can it be detected by a movement of the car?

A. Yes; the car usually makes a lateral movement.

Q. 91. What are the principal causes of flat wheels, and chipped flanges on wheels?

A. Flat wheels are caused by sliding on the rail. This is caused by the brakes being set too hard. Chipped flanges are usually caused by striking sharp curves, special work or switches at too high a speed.

Q. 92. How is a motor raised with its own power when dropped?

A. By putting on the power with the reverse handle in the right position to cause the motor to be revolved around the axle. The brakes should be set on the car to keep it from moving.

Q. 93. If a fuse is not properly secured with a full contact service at terminal is it liable to melt out, and if so, why?

A. Yes. The resistance of the contact will cause the fuse to heat at the point of contact.

Q. 94. Are covered fuses in more general use than uncovered ones, and why?

A. Yes, in small sizes. Because they are more reliable in breaking the circuit, and are easier to replace.

Q. 95. Explain why a car equipped with two motors, and which cannot be operated on the series position, may be operated on the parallel positions?

A. This could be done when a motor lead is broken, or a brush out on one motor. When the controller is thrown to the parallel position the second motor is put into circuit.

Q. 96. If in starting to take a car from the barn, it should be found that the controller handle cannot be thrown beyond the last series position, to what cause could this be attributed?

A. That a motor was cut out.

Q. 97. What should be done in case a contact wiper in the controller should become bent or broken?

A. Repair, or replace if possible, if not, remove.

Q. 98. Before a car is turned in, or delivered to a relief man, what should be done by the motorman in charge?

A. The motorman should deliver his car with the controllers thrown to off, stop and reverse switches set at center. Both overhead switches should be thrown to off position, and trolley wheel removed from wire.

Q. 99. How should sand be used to prevent flat wheels before making a stop on a slippery rail?

A. Start putting on sand before applying brakes.

Q. 100. Who is supposed to have charge of a car?

A. The conductor has full charge as regards when the car shall be started, and stopped, and when it shall be run. The motorman has full charge as regards the operation of the car.

Q. 101. When the car is in motion, why should a sharp lookout be kept at all times?

A. So as not to run into anything on the track.

Q. 102. What appliances should motormen have on car at all times?

A. Pliers, screw driver, monkey wrench, red flag and necessary fuses.

Q. 103. When a ring of fire passes around a commutator what should be done to avoid further damage?

A. Cut out motor.

Q. 104. What method would be applied in case the car wheels slip in making a grade?

A. Use sand.

Q. 105. Is one permitted to reverse motors, if so, under what conditions?

A. Yes. In case brakes fail, or when something gets on the track so close to the car that there is not time to apply brakes.

Q. 106. In reversing motors what is the first thing to be done?

A. Throw reverse handle.

Q. 106. Should the trolley wire be down what should be done?

A. Notify repair men, and using some insulating material clear the ends of the wire from grounds.

REPAIRS.

Q. 107. In making an examination of a car motor, how is access obtained to the motor?

A. Through a trap door provided in the floor of car through which the motor armature may be readily examined.

Q. 108. In mounting repaired motors what precaution should be taken to insure secure work?

A. The axle keys in the axle, and axle gears should be securely fitted to prevent gears from working loose; all bolts should be made tight.

Q. 109. What precautions should be taken when cotter pins are used?

A. They should be opened sufficiently to prevent them from slipping out.

Q. 110. What is the best way to examine a car with a view of ascertaining and making repairs needed?

A. If there is a pit, the car should be placed over it, and the mechanism examined from beneath. If there is no pit the examination of the motors should be made through the trap, or floor doors of the car from above.

Q. 111. What should be done where armature bearings show excessive temperature and the grease in the cups has melted out?

A. The bearing caps should be removed, and if the metal has been burned sufficient to cause injury, the bearings should be replaced by new ones.

Q. 112. If upon examining armature, and commutator brushes, they should be found in any way impaired, what should be done?

A. If the defects are slight and of such character as to enable the parts to be repaired or readjusted without removal, such repairs may be done on the spot, but if there are evidences of wear or other irregularities calling for renewals or replacing of parts, they should be dismantled at once and taken to the shop for complete overhauling. The same course should be pursued in case of defective circuit breakers, car wiring, and in fact any and every part of the car equipment.

Q. 113. What is the result when proper clearance between the pole pieces and the armature is not maintained?

A. The armature strikes the pole pieces and is thereby seriously damaged.

Q. 114. What is the immediate cause of the armature striking the pole pieces?

A. The armature is permitted to run in bearings which are worn.

Q. 115. Is special care required in handling armatures in process of repair, or in handling them around the shops?

A. Yes; care must be exercised to prevent abrasion of the insulating materials.

Q. 116. When armatures have been repaired and waiting to be mounted, where should they be kept?

A. They should be kept in a dry location, and well protected from dust and mechanical injury.

Q. 117. What is liable to occur in repairing motors if loose nuts or bolts are not firmly secured?

A. They may drop down into the motor frame and cause serious trouble. Or if bolts should become loose, excessive strains occur which cause breakage of parts.

Q. 118. Should the motormen sometimes examine the commutators when car is under full headway?

A. Yes, in order to see that the brush tension is right, and that there is no flashing and that the commutators may be kept clean.

Q. 119. What should be done when a commutator is found to be rough?

A. The commutator should be turned and put in true and smooth condition. Ridges and dirt on the commutator cause serious injury to the apparatus, and sometimes total destruction.

Q. 120. What is the result of leaving drain plugs in the bottom of the magnet frame?

A. Water may accumulate and ground the field coils.

Q. 121. What should be done when brushes are worn too short?

A. They must not be allowed to wear too short, because then the brush holders would bear on the commutator. Before they are too much worn they should be replaced by new ones.

Q. 122. What precaution should be observed in replacing old brushes by new ones?

A. It is important to use brushes of the proper size and length.

Q. 123. How is the proper length and size of the brush determined?

A. By reference to the manufacturer's list of brushes for use with the standard railway motors, which gives the type and number of motor; the number, length, breadth and thickness of brushes.

Q. 124. What precautions should be taken to prevent injury to controllers after they have been repaired and are ready to be put in service?

A. After they have been mounted on the car all dust should be blown out with an air blast to prevent controller frames from becoming grounded.

Q. 125. When the figures and segment tips become rough what should be done?

A. They should be sandpapered, or filed or a little vaseline applied, but before applying the vaseline the parts should be made free from dust by blowing.

Q. 126. How are trolley stands kept in good order?

A. By proper and sufficient lubrication, so as to permit of free turning.

Q. 127. Should trolley wheels be permitted to wear until they begin to cause flashing?

A. No; as soon as they show signs of undue wear they should be replaced, as when they flash injury to the overhead line is liable to follow.

Q. 128. When a rheostat has been repaired, what precaution should be taken in remounting it?

A. It should be placed so as to protect it from moisture. That is, water and mud which might be thrown into it by the wheels.

Q. 129. What size bolts, and how many should be used for securing rheostat to the car body?

A. Four ½″ bolts should be used, and where necessary planks should first be attached to the car sills to support the rheostat.

Q. 130. What should first be done when replacing repaired trolley poles on a car?

A. The trolley board on the roof of the car should be examined to see if it is in good order, so that it will afford a suitable support for the trolley base.

Q. 131. In mounting circuit breakers where should they be located in the car?

A. In the vestibule of the car, at the right of the motorman and within easy reach.

Q. 132. Why are they inclosed in a box?

A. To deaden the noise.

Q. 133. How much space should be allowed between the blow-out chute and the woodwork of a car?

A. Sufficient to avoid discoloring the paint.

Q. 134. How should the connection be made for circuit breakers?

A. They should be connected in parallel, so that the car can be operated by either controller with one breaker setting.

Q. 135. Do circuit breakers need any special care?

A. Yes; the working parts should be kept clean and the blow-out chute free from carbon deposits.

Q. 136. What should be done when the contacts become rough?

A. They should be rubbed smooth, and an occasional application of a little vaseline will lubricate and tend to keep them in good condition.

Q. 137. What are the main things to be considered in making repairs of the power wiring of the car?

A. The repairs should be made in such manner as to leave all wires underneath, or inside of the car well protected from mechanical injury through strains due to rocking of the car body or from chafing by coming in contact with other parts of the equipment.

Q. 138. Will the heat from rheostats and heaters seriously affect the insulation of cables and wires?

A. Yes; they should be located with a view to prevent injury from heat.

Q. 139. What precaution should be observed in placing wires of extreme difference of potential?

A. They should not be placed in close proximity.

Q. 140. What attention should permanent taps and splices receive from the repair man?

A. He should solder all permanent splices and thoroughly tape them.

Q. 141. Why should cables and wires be securely supported?

A. To minimize vibration.

Q. 142. What should be done to set-screws or clap connections at controllers, rheostats, fuses, circuit breakers and other points?

A. They should be examined and if found loose should be made tight and firm.

Q. 143. As a general rule, where should the cables be located?

A. In dry out of the way positions. Sometimes it is well to run them in a boxed compartment carried along the car sills from end to end of the car.

Q. 144. On open cars where should the cables be located?

A. Under the car bodies, under the platforms as near the center line as possible.

Q. 145. What should be done to prevent water and mud thrown by the wheels from reaching the cables?

A. They should be passed around holsters.

Q. 146. How should cables be placed on double truck cars?

A. They should be placed in such manner as to prevent the wheels from cutting them when rounding sharp curves.

Q. 147. How should cables be placed in closed cars with seats running lengthwise?

A. They should be carried under the seats and supported on brackets, or with leather cleats to keep them off the car floor.

Q. 148. How should the cables be located so as not to interfere with the car heaters?

A. It is better to run them under than over the heaters.

Q. 149. How should taps from the cables to the motors be arranged?

A. They should be as short as possible with sufficient slack to prevent strains, and on double-truck equipments a coiled metal armor should preferably be used, and all connections between these taps and the motor leads should be thoroughly made.

Q. 150. What kind of wire should be used to prevent breaking of the wires, and constant arcing?

A. Stranded wires.

Q. 151. Why should the main wire from the trolley be brought in a protected place inside the roof?

A. So that water will not follow the wire.

Q. 152. What should be done to taps and joints after they are soldered?

A. They should be covered with splicing compound and adhesive tape.

Q. 153. Are wires liable to be injured by car doors?

A. Yes; and they should be placed with a view to prevent violent contact with the doors when being opened or closed.

Q. 154. What should be done to commutators showing flat or high bars?

A. They should be ground or turned.

Q. 155. When has grinding certain advantages over turning?

A. Unless the commutator is in very bad shape grinding removes less material, requires less skill, leaves the commutator in better shape and obviates the necessity of sandpapering.

Q. 156. What rules should be followed in grinding equipments?

A. The rules laid down by the manufacturers.

Q. 157. What precautions should be taken in turning the commutator?

A. The shaft should be blocked to prevent end play.

Q. 158. What should be the peripheral speed of the commutator when grinding?

A. As high as can be safely used without burning the tool. Not over 300 feet per minute.

Q. 159. How is this speed obtained for small machines where driving motors or power are not available?

A. By means of a windlass turned by hand on the shaft extension.

Q. 160. How is the speed obtained for large machines?

A. They should be motor driven through a pulley mounted on the same point.

Q. 161. What should be done before turning the commutator?

A. A suitable shield should be made to prevent chips or dust from working into the armature.

Q. 162. How can this be done?

A. By using a strip of cotton several inches wider than the length of the commutator end connections and long enough to encircle the armature.

Q. 163. How are the inside ends made secure?

A. By binding them with a cord around the commutator as close as possible to the end connections.

Q. 164. How are the outside ends secured?

A. By drawing them well over the armature and binding them down with cord.

Q. 165. What is the best tool for turning?

A. A side cutting tool, the cutting side and point having considerably more rake than is customary with steel or iron.

Q. 166. What should be done to the commutator after turning?

A. The end of the commutator should be rounded off with a file to a radius of at least 1/16 of an inch.

Q. 167. What should be done next?

A. The commutator should be examined bar by bar to see that no small articles of copper are imbedded in the mica.

Q. 168. What is the last thing to be done after the commutator has been turned?

A. It should be polished with sandpaper and oil.

Q. 169. Should emery ever be used for polishing or grinding a commutator?

A. No; not under any circumstances should it ever be used.

ACCUMULATOR RAILWAY CARS OF THE PRUSSIAN STATE RAILWAYS.

The Prussian State Railways have now put into service new accumulator double cars, which, in addition to the large through trains, are to be used for making intermediate connections on their main and branch lines, where there is a heavy traffic. The first official run of the double cars, which were supplied by Felten & Guilleaume-Lahmeyerwerke, Frankfort-on-the-Main, took place on a twenty-seven-mile stretch between Mayence and Gaualgesheim-Münster. Not only was the normal speed desired reached, but on certain parts of the track this was exceeded. The braking tests also gave satisfactory results. Among the features of particular interest in the equipment is the brake handle, which, on being released, automatically switches off the current and brings an emergency brake into immediate action. In order to start the motor the driver must press down the handle, which, under normal conditions, is pressed upward by a spring. This operation closes two contacts, which in turn close a main-circuit, automatic circuit-breaker. One of the two contacts remains rigidly connected with the controller, while the other is only connected with it when the driver presses down the handle. Should the driver release his hold upon the controller handle while it is in either a running, or braking position, it immediately flies up, disconnecting the movable contact, which returns to its off position by means of a spring. By this means the main circuit is interrupted, and an electrically operated valve on the compressed-air brake is opened. The weight of the driver's hand is sufficient to hold the handle down, and is not so tiring as with a push-button release. On starting up, the motors are both in series, and both in parallel when running on an open stretch. A reversing switch, by means of which the train may be run either forward or backward, is fitted in the driver's cab. By reversing the direction of rotation of the motors, the headlights on the train at the same time are automatically reversed. On the trial run it was found that the train, when traveling at a speed of thirty-six miles an hour, could be brought to rest when using the compressed-air brake alone in 600 feet, when using both compressed-air and electrical brakes in 300 feet. The cars are also fitted with a small mechanical brake, which may be operated from each driver's cab by means of a hand-wheel. The electrical equipment of each complete train consists of two interpole series motors of the totally-enclosed, water-tight

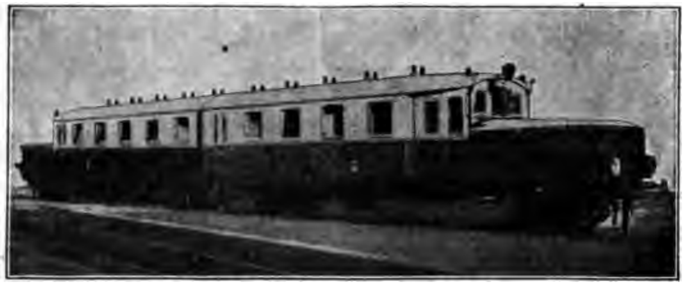


Fig. 52. General View of an Accumulator Double-Car on the Prussian State Railways.

type, each giving fifty horsepower on a two-hour rating, or eighty-five horsepower on a one-hour rating. They are fitted on the one side with the reduction gear on the shaft, and on the other side suspended by means of springs to the under side of the frame. The battery consists of 168 cells, fitted in two compartments, eighty-four in each, in front of the driver's cab. The total pressure is 310 volts, and the capacity 368 ampere-hours on a one-hour rating. The distance of sixty-two miles may be run on one charge, and a maximum speed of thirty-one miles can be attained on the level.

THE SINGLE-PHASE COMMUTATOR-TYPE MOTOR.*

The broad statement may be made that it is no more difficult to commutate an alternating current than an equal direct current. Such a statement would appear to be entirely contrary to the usual experience, but a little study of the matter will show where the apparent discrepancy lies. In commutator type, alternating-current motors, as usually built, a relatively large number of commutator bars passes under the brush during one alternation of the supply current. While the current supplied is varying from zero to maximum value, and back to zero, possibly 50 bars have been passed under the brush, and therefore 50 coils in the armature have been reversed, or commutated. Some of these reversals occur at the top of the current wave which has a value of about 40 per cent higher than the mean or effective value which is read by the ammeter. The motor is therefore at times commutating 40 per cent higher current than that indicated by the instruments. It is thus evident that in comparing the commutation of 100 amperes alternating current we should actually compare the direct current with 141 amperes alternating. In other words, for commutating equal currents alternating-current, or direct current, the alternating-current ammeter should register only 71 per cent as much current as the direct current.

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*From a paper presented at the Philadelphia Section of the American Institute of Electrical Engineers. Revised by the Author, B. G. Lamme.

Another way of expressing it is that we have to commutate the top, or maximum of the alternating-current wave, while our instruments only record the mean value.

If the above represented the only difference between the alternating current and direct current, the problem to be solved in commutation of alternating current would not be serious. However, the current to be commutated by an alternating-current motor is not merely the working current supplied to the motor and measured by the ammeter, but there is, in addition, a current which is generated in the motor itself, both at standstill, and during rotation, which has to be reversed or commutated along with the working current. It is this latter current, usually called the local or short-circuit current, which has been the source of greatest trouble in commutating alternating current; for this short-circuit current may have a value anywhere from three to ten times the working current, depending on the design of the machine.

Therefore, in comparing the commutation of an alternating current, as indicated by an ammeter with an equal direct current, we should, in reality, consider that the alternating-current motor is commutating a maximum current from five to ten times the value of the indicated current. Furthermore it would not do to reduce the ammeter current to one-fifth or one-tenth value in order to compare commutation with direct current, because by so doing we would simply be reducing the small applied component of the total current commutated by the brushes, the local or short-circuit current still retaining a rather high value. In order to compare with direct current commutation, it would be necessary for the total maximum of the combined supply and the short circuit to be reduced to the same value as direct current. Hence the local current in the armature turn short-circuited by the brush is the source of practically all the trouble in commutating alternating currents. Fig. 53 illustrates a portion of the field, and armature structure of a commutator type alternating-current motor. It will be noted that the armature conductor, which is in the neutral position between poles, surrounds the magnetic flux from the field pole, just as the field turns themselves surround it. The field flux being alternating, this armature turn will have set up in it an electro-motive force of the same value as one of the field turns. Short circuiting the two ends of this armature turn should have the same effect as short-circuiting one of the field turns, which is the same as short circuiting a turn on a transformer. Such a short-circuited turn, if of sufficiently low resistance, should have as many ampere turns set up in it as there are field ampere turns. In single phase motors of good design the field ampere turns per pole are about twelve to fifteen times the normal ampere turns in any one armature coil. Therefore if the armature coil in the position shown in Fig. 53 should have its ends closed on themselves the current in this coil would rise to a value of

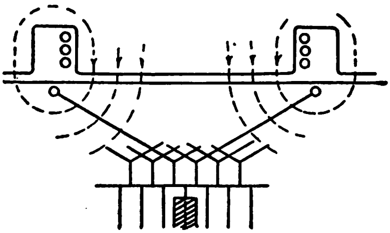

Fig. 53.

twelve to fifteen times normal. In reality it would not rise quite this much, because this armature turn is placed on a separate core from the field, or magnetizing turns with an air-gap between, so that the magnetic leakage between the primary (or field winding) and this secondary (or armature winding) would tend to protect this coil somewhat, just as leakage between the primary and secondary windings of a transformer tends to reduce the secondary electromotive force and current. Also, this armature coil is embedded in slots, thus adding somewhat to its self-induction, and tending further to reduce the short-circuit current. In consequence, with its ends closed together the current in this armature coil would probably not rise more than ten to twelve times above normal value under any condition. It is evident, therefore, that if the brush, shown in Fig. 53 as bridging across two commutator bars, to which the ends of this coil are connected, is of copper, or other low-resistance material, then there could be an enormous local current set up in the coil when thus short-circuited by the brush. This local current of about ten times the normal working current would have to be commutated as the brush moves from bar to bar, and therefore the operation of the machine would be similar to that of a direct-current motor if overloaded about ten times in current. In other words, there would be vicious sparking.

Even if the low resistance brush were replaced by one of ordinary carbon, the short-circuiting current would still be relatively high, due to the fact that it is not allowable to make the brush contact of very high resistance, by reducing the size or number of the brushes, because these same brushes must carry the working current supplied to the motor, and there must be brush capacity sufficient to handle this current. This brush capacity will, in practice, be of such amount that the resistance in bridging from one bar to the next is still rather low, although much higher than if a copper brush were used. Experience shows that, with not more than four or five volts generated in this short-circuited coil by the field flux, the resistance of the carbons at the contact with the commutator would be such that a short-circuit current of three to four times the normal working current in the coil can still flow. Therefore, if the motor were equipped with carbon brushes and had but four or five volts generated in the short-circuit coil, the motor would have to commutate the main or working current, and also a short-circuit current of possibly three times the amount. This short-circuit current would also have a maximum or top of its current wave. Assuming 100 amperes as the current supplied to the motor, the machine therefore actually commutates a supply current of 141 amperes, and an additional short-circuit current of possibly three times this value, or from 400 to 500 amperes; therefore, the motor actually commutates the equivalent of about 600 amperes direct current when the alternating current ammeter is reading 100. It is evident from this that any one who tries to commutate alternating current with an ordinary type of commutating machine would at once draw the conclusion that alternating current in itself is very difficult to commutate, naturally overlooking the fact that it is the excessive current handled by the brush that is back of the trouble, and not the current indicated by the ammeter.

All efforts of designers of alternating-current commutator motors have been in the direction of reducing or eliminating this local current. The present success of the motor, in the various forms brought out, is largely due to the fact that this current has been successfully reduced to so low a value that it does not materially add to the difficulties of commutating the main current. No successful method has yet been practically developed for entirely overcoming the effects of this short-circuit current under all conditions, from standstill to highest speed. Some of the corrective methods developed almost eliminate this current at a certain speed or speeds, but have little or no corrective effect under other conditions; other methods do not effect a complete correction at any speed, but have a relatively good effect at all speeds and under all conditions. The former methods would appear to be applicable to motors which run at, or near, a certain speed for a large part of the time; the latter method would be more applicable to those cases where the motor is liable to be operated for considerable periods with practically any speed, from standstill to the highest. While several methods have been brought forward for correcting local current when the motor has obtained speed, yet up to the present time but one successful method has been developed for materially reducing this current at standstill, or very low speeds. It may be suggested that the short-circuit voltage per coil be reduced to so low a value, say four or five volts, that the local current is not excessive and does not produce undue sparking. This would certainly reduce the sparking difficulty, but is open to the very great objection that the capacity of the motor is directely affected by a reduction in the short-circuit voltage. This voltage per turn in the armature coil is a direct function of the value of the alternating field-flux and its frequency. Assuming a given frequency, then the short-circuit voltage is a direct function of the induction per field pole, and the lower the short-circuit voltage, the lower must be the field flux. But the output of the machine, or the torque with a given speed, is proportional to the product of the field flux per pole by the armature ampere turns. In a given size of armature the maximum permissible number of ampere turns is dependent upon mechanical, and heating considerations, and therefore with a given armature, the torque of the motor is a direct function of the field flux. Using the maximum permissible armature ampere turns, the output of a given motor would be very low if the field flux were so low that the short-circuit voltage would not be more than three or four volts. Increasing the field induction, and therefore increasing the short-circuit voltage, increases the output.

Experience shows that on large motors, such as required for railway work, the induction per pole must necessarily be so high that the electromotive force in the short-circuit coil must be about double the figure just given; therefore, with such heavy flux the short-circuited current will necessarily be excessive, unless some corrective means is used for reducing it.

I will consider the standstill or low-speed condition first. For this condition only one practical arrangement has so far been suggested for reducing the local current to a reasonably low value compared with the working current. This method involves the use of preventive leads, or, as they are sometimes called, resistance leads. These consist of resistances connected between the commutator bars and the armature conductors. Fig. 54 illustrates the arrangement. The armature is wound like a direct-current machine, except that the end of one armature coil is connected directly to the beginning of the next without being placed in the commutator. Between these connections separate leads are carried to the commutator bars; and in these leads sufficient resistance is placed to cut down the short-circuit current. The arrangement is very similar in effect to the preventive coils used in connection with step-by-step voltage regulators, which have been in use for many years. In passing from one step to the next on such regulators, it is common practice to introduce a preventive coil, or resistance in such a way that the two contact bars are bridged only through this preventive device.

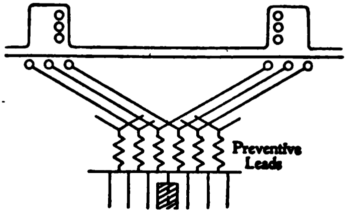

Fig. 54.

In an armature winding arranged in this way, the working current is introduced through the brushes and the leads to the armature winding proper. After entering the winding, the current does not pass through the resistance leads, because the connections between coils are made beyond these leads. In consequence, only a very small number of these leads are in circuit at any one time; when the armature is in motion all the leads carry current in turn, so that the average loss in any one lead is very small. As the brush generally bridges across two or more commutator bars, there is usually more than one lead in circuit, but generally not more than three. When the brush is bridging across two bars, there is not only the working current passing into the two leads connected by these two bars, but there is the local current, before described, which passes in through one lead, through an armature turn, then back through the next lead to the brush. There are losses in these two leads, due to these two currents. By increasing the resistance, the loss due to the working current is increased, but at the same time the short-circuit current is decreased. As the loss due to this latter is equal to the square of the current multiplied by the resistance, it is evident that increasing this resistance will cut down the loss due to the local current in direct proportion as the resistance is increased. When the working current is much smaller in value than the short-circuit current, an increase in the resistance of the leads does not increase the loss due to the working current as much as it decreases the loss due to the short-circuit current. Both theory and practice show that when the resistance in the leads is so proportioned that the short-circuit current in the coil is equal to the normal working current, the total losses are a minimum. Calculation, as well as experience, indicates that a variation of twenty to thirty per cent at either side of this theoretically best resistance gives but a very slight increase in loss, so there is a considerable flexibility in the adjustment of this resistance. The resistance of the brush contacts, and of the coil itself must be included with the resistance of the leads in determining the best value. In practice it is found that with ordinary medium-resistance brushes, the resistance in the leads themselves should be about four or five times as great as the resistance in the brush contact and the coil; that is, it is usual to calculate the total necessary resistance required and then place about seventy or eighty per cent of it in the leads themselves. When leads of the proper proportion are added to the motor, it is found that practically twice as high field flux can be used as before, with the same sparking and burning tendency as when the lower flux is used without such leads. But even with six to eight volts per commutator bar as a limit, a handicap is encountered in the design of the motors, especially when the frequency is taken into account. This limited voltage between bars also indicates at once why single-phase railway motors are wound for such relatively low armature voltages. Direct-current railway motors commonly use from 12 to 20 volts per commutator bar, or from 2 to 2.5 times the usual practice on alternating-current motors. With this low voltage between bars in alternating current machines, with the largest practicable number of bars, the armature voltages become 200 to 250, or about forty per cent of the usual direct-current voltages. The choice of low voltage should, therefore, not be considered as simply a whim of the designers; it is a necessity which they would gladly avoid if possible.

Assuming preventive leads of the best proportions, let us again compare the current to be commutated in an alternating current motor with that of the direct-current. Considering the ammeter reading as 100, the working alternating current has a maximum value of 140 and in addition there is a short-circuit current of the same value. Even under this best condition, the alternating-current motor must commutate a current several times as large as in the corresponding direct-current motor. The design of such a motor, therefore, is a rather difficult problem, even under the best conditions.

I will now take up the question of power-factor in the single-phase commutator motor. In a direct-current motor we have two electromotive forces which add up equal to the applied electromotive force; namely, the counter electromotive force due to rotation of the armature winding in the magnetic field, and the electromotive force absorbed in the resistance of the windings and rheostat. In the alternating-current motor there are these two electromotive forces, and there is also another one not found in the direct-current machine; namely, the electromotive force of self-induction of the armature and field windings due to the alternating magnetic flux in the motor. This inductive electromotive force exerts a far greater influence than the ohmic electromotive force, for it has much higher values.

The inductive electromotive force lies principally in the main field or exciting winding of the alternating-current motor. There is a certain voltage per turn generated in the field coils, depending upon the amount of the field flux and its frequency, as stated before. This electromotive force per field turn is practically of the same value as the short-circuit, electromotive force generated in the armature coil, as already referred to. I have stated that a short-circuit voltage of three or four volts per armature turn gave prohibitive designs and that it was necessary practically to double this. This means that the field coils also have six to eight volts per turn generated in them. The total number of field turns must, therefore, be very small in order to keep down the field electromotive force, for this represents simply a choke coil in series with the armature. If the armature counter electromotive force should be 200 volts, for instance, which is rather high in practice with 25-cycle motors, then a field self-induction of half this value would allow about 14 turns total in the field winding. Compare this with direct-current motors with 150 to 200 field turns for 550 volts, or 60 to 80 turns for 220 volts. The alternating-current 25-cycle motor, therefore, can have only about 20 to 25 per cent as many field turns as the ordinary direct-current motor. This fact makes it particularly hard to design large motors where there must be many poles. In the single-phase motor, the induction per pole being limited by the permissible short-circuit voltage, it is necessary to use a large number of poles for heavy torques; but the total number of field turns must remain practically constant on account of the self-induction, while in reality the number of turns should be increased as the number of poles is increased. With a given number of poles, we may have just sufficient field turns to magnetize the motor up to the required point; but if a large number of poles should be required, then we at once lack field turns, and must either reduce the field induction, and thus reduce the output, or must add more field turns, and thus get a higher self-induction, or choking action in the field, with a consequent reduction in power-factor. Here is where a lower frequency comes in to advantage, for, with the same relative inductive effect, the field turns can be increased directly as the frequency is decreased. The use of 15 cycles permits 67 per cent more field turns than 25 cycles and raises our permissible magnetizing limits enormously. This problem is encountered particularly in gearless locomotive motors of large capacity. For increased capacity the driving wheels are made larger, thus permitting a larger diameter of motor, the length, axlewise, being fixed. But with increased diameter of drivers, the number of revolutions is decreased for a given number of miles per hour. With 25 cycle motors we soon encounter the above mentioned limiting condition in field turns; beyond this point the characteristics of the motor must be sacrificed, and even doing this, we soon reach prohibitive limits. By dropping the frequency to 15 cycles, for instance, we change the whole situation. The induction per pole can be increased, and the number of poles, if desired, can also be increased. The practical result is that, in the case of a high-speed passenger locomotive, with gearless motors, a 700 hp., 15 cycle motor can be put in on the same diameter of drivers as required for a 500 hp., 25 cycle motor. Also a 500 hp., 15 cycle motor may be put on the same drivers as a 300 horsepower, 25 cycle motor. At the same time these 15 cycle motors have better all around characteristics than the 25 cycle machines, as regards efficiency, power-factor, starting, overload commutation, etc. Returning to the design of the motor, there is one other electromotive force of self-induction which may be considered; namely, that generated in the armature winding, and in the opposing winding in the pole face, usually called the neutralizing or compensating winding.

Fig. 55 shows a section of the field and armature corresponding to the usual direct-current motor, or an alternating-current motor without compensating winding. In the direct-current motor, the armature ampere-turns lying under the pole face tend to set up a local field around themselves, producing what is known as cross-induction. This produces no harmful effect, except in crowding the field induction to one edge of the pole, thus shifting the magnetic field slightly and possibly effecting the commutation in a small degree. But if the armature is carrying alternating current, this cross flux will generate an electromotive force in the armature winding, and this will be added to the field self-induction, thus increasing the self-induction or choking action of the machine. As the armature turns on such motors are much greater, in proportion, than the field turns, it is evident that the ampere-turns under the pole face can exert a relatively great cross-magnetizing effect. This high cross-magnetization generates a high armature self-induction, which may be almost as much as the field self-induction. Further, this great cross-induction would tend to shift the magnetic field quite appreciably, thus affecting the commutation to some extent.

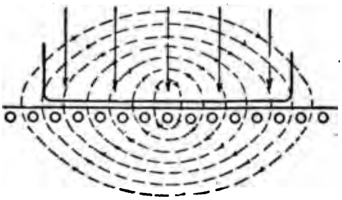

Fig. 55.

To overcome this serious objection, the neutralizing winding is added. This is a winding embedded in the pole face and so arranged that it opposes the armature cross-magnetizing action. The arrangement is shown in Fig. 56. As it opposes and thus neutralizes the cross-induction set up by the armature winding, it eliminates the self-induction due to the cross-magnetization. It also prevents shifting of the magnetic field, and thus eliminates its injurious effect on commutation. As the cross-flux is practically cut out, the armature winding becomes relatively non-inductive. There is, however, a small self-induction in the armature and neutralizing windings, due to the small flux which can be set up in the space between the two windings.

I have stated that the field turns of the alternating-current motor can only be 20 to 25 per cent as many as in ordinary direct-current practice. It may be questioned how the field can be magnetized with so few field turns. This has been one of the most difficult problems in the motor. Obviously, one solution would be the use of a very small air-gap, but in railway practice there are objections to making the air-gap unduly small. Furthermore, if the armature has large open slots, as shown in Fig. 57, experience shows that a reduction in the clearance between the armature, and field iron does not represent a corresponding decrease in the effective length of the air-gap, due to the fact that the fringing of the magnetic flux from the tooth tip of the pole face, changes as the air-gap is varied. The most effective construction yet used consists in making the armature slots of the partially closed type as in the secondary of an induction motor.

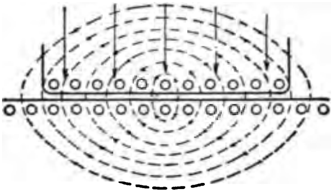

Fig. 56.

With this construction practically the whole armature surface under the pole becomes effective, and the true length of air-gap is practically the same as the distance from iron to iron. With the increased effective surface, due to this construction, the length of air-gap need not be unduly decreased, which is of considerable importance in railway work.

A further assistance in reducing the required field turns is, the field construction used in the single-phase motor. The magnetic circuit consists of laminations of high permeability, and usually without joints across the magnetic path. The iron is also worked either below the bend in the saturation curve or, at most, only slightly up on the bend, except in the case of very low frequency motors where more field turns are permissible. Taking the whole magnetic circuit into account, on 25 cycle motors about 80 per cent of the whole field excitation is expended in the air-gap, while in direct-current motors, even with a much larger air-gap, as much as 40 or 50 per cent of the magnetization may be expended in the iron, and in the joints. This armature construction, with the partly closed slots, has been found very effective in large, slow-speed, single-phase motors in which a relatively large number of poles is required. This con-

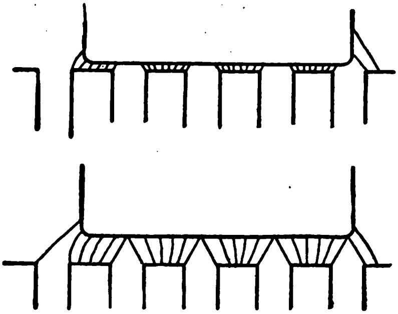

Fig. 57.

struction is used on the New Haven 250 hp., 25-cycle motors; also on the 500 hp., 15-cycle motors on the locomotive which was exhibited at Atlantic City at the Street Railway convention, October, 1907. Geared motors for interurban service can be constructed with ordinary open slots with bands, and many have been built that way. The semi-closed slot, however, allows more economical field excitation.

It may be asked what the objection is to low power-factors on single-phase railway motors, aside from the increased wattless load on the generating station, and transmission circuits. There is an objection to the low power-factor in such motors, a very serious one. This lies in the greatly reduced margin for overload torque in case the supply voltage is lowered. In railway work it is generally the abnormal loads or torques which cause a reduction in the line voltage; that is, the overload decreases the trolley voltage just when a good voltage condition is most necessary. This is true of direct current as well as alternating current. In the direct-current motor, however, such reduction in voltage simply means reduced speed, but in the alternating-current motor the effect may be more serious.

To illustrate, assume a motor with a power-factor of 90 per cent at full load. The energy component of the input being 90 per cent, the inductive component is about 44 per cent or, putting it in terms of electromotive force, the inductive volts of the motor are 44 per cent of the terminal voltage. Neglecting the resistance of the motor, a supplied electromotive force of 44 per cent of the rated voltage would just drive full-load current through it and develop full-load torque. With full voltage applied, the motor could develop from five to six times full-load torque. Under abnormal conditions a drop of 30 per cent in the line voltage would still give sufficient voltage at the motor terminals to develop two and one-half, to three times full-load torque. Considering next a motor with 80 per cent power-factor at full load: the inductive voltage would then become 60 per cent of the terminal voltage, and therefore 60 per cent of the rated voltage must be applied to send full-load current through the motor. This neglects the resistance of the motor, which, if included, means that slightly more than 60 per cent of the voltage is required. With full voltage applied, this motor would develop about three or four time the rated torque. With 30 per cent drop in the line voltage, the motor could develop from one and a half, to two times the rated torque, which is hardly enough for an emergency condition.

Taking next a motor with 70 per cent power-factor, at full-load it would require 70 per cent of the rated voltage to send full-load current through the motor; with 30 per cent drop in line voltage the motor could just develop full-load torque, and even with 15 per cent drop it would develop only about one and one-half times rated torque. As 15 per cent drop is liable to occur on any ordinary system, this latter motor would be a very unsafe one.

It is evident from the above that it would be bad practice in railway work to install motors with very low full-load power-factors. In general, the higher the power-factor the more satisfactory will be the service, other things being equal.

I have endeavored to explain some of the problems which have been encountered in the design of single-phase commutator railway motors of sizes suitable for all classes of railway service. Here is a type of machine which has been known for a great many years, but which, until within the last few years, has been considered utterly bad. In a comparatively short time it has been changed from what was considered an unworkable machine, to a highly satisfactory one, and this has been accomplished, not by any radically new discoveries, but by the common-sense application of well known principles to overcome the apparently inherent defects of the type. As an indication that the motor is making progress in the railway field, I will mention that the first commercial single-phase railway motors have not been in use more than four or five years, and yet at the present time there have been sold by the various manufacturers in this country and Europe, a total capacity of approximately 200,000 to 250,000 hp., a very considerable part of which has been put in operation. Considering that the motor was a newcomer in a well established field, the above record is astonishing. However, it may be safely predicted that what has been done in the last five years will hardly make a showing, compared with what will be done during the next five years, for the real field for such motors, namely, heavy railway work, has hardly been touched.

CURRENTS

Three systems are generally used to supply the current to the motor cars in Electric Railway service.

By the Direct Current system the entire current flows into the trolley wire, and an auxiliary wire or feeder cable. This cable is supported on the same poles as the trolley wire. The current leaves the dynamo at the power station, passes through the trolley wire, and is collected by the trolley wheels of the cars along the line, passes along to the controllers, then through the motors, where it performs its work, by causing the armature to revolve, and then on through the truck axle and wheels to the rail, and back through the rail and return feeders to the dynamo, thus completing the circuit.

The Alternating Current system works practically upon the same general plan as the direct current, and the current is generated in the same way with the exception that the connection between the armature coils and brushes is different. The connection of the brushes at the commutator end of the armature in the alternating current system is effected by the brushes slipping over two bars bent in the form of rings, instead of over a number of copper bars from which the brushes for the direct current system collect from the rotating commutator the numerous little currents passing through the armature in many directions, and unite them into one main current. The slipping of the brushes over these rings takes the currents which are flowing in different directions through the armature coils, and feeds them as the different coils in the armature pass by the north and south poles of the generator, to the line in opposite directions instead of all in one direction and hence the term "alternating" current as is implied by the path of the current in the circuit; first in one direction and then in the other.

Where high voltages are used current may be transmitted over long distances without much loss, and the alternating current provides a system for the raising of the voltage by the employment of transformers which are installed in the general circuits. This is effected by means of a transformer at the power station, which raises the voltage of the current and then transmits it over wires, termed transmission lines, to distant points. The pressure of the current is then reduced by other transformers at the end of the transmission line, to a lower voltage suitable for the safe operation of the cars, and at this reduced voltage the current is supplied to the trolley wire.

Unlike the direct current the alternating current can be raised in pressure without the use of a generator, by means of the transformer.

THE TRANSFORMER. This device consists of a large piece of iron wound with two coils of wire. An alternating current passing through one of these coils of wire, energizes the iron around which it is wound, creating lines of force in the iron. This, subject to a well-known characteristic of electricity, induces a current in the other coil to which no current has been fed, and the degree of pressure of the current thus induced in the second coil is proportionate to the number of turns in each coil. If the number of turns in the second coil is greater than that of the coil to which the current has been fed, the pressure of current generated in the second by the current of the first coil will be greater than that of the first, and vice versa.

When there are alternating current generators at the power station, the pressure of currents can be raised considerably in voltage—as much as 40,000 volts—by feeding the current to these converters, and the pressure at which it is desirable to feed the current to the trolley wire is readily determined by the ratio between the number of turns constituting the windings of the two coils.

The difference in the practical results of operation as referred to the movement of cars over roads using either the direct current, or alternating current systems is negligible. In the alternating current system, and which is also termed the single phase system, motors of a type are used, which may be operated by either the direct or alternating current.

BY THE ALTERNATING-CURRENT-DIRECT-CURRENT SYSTEM. The feeding of long lines with the minimum of expense is obtained by the employment of alternating current generators, which raise the current pressure so that it may be transmitted over considerable distances along the line to points where by means of an alternating-current motor and direct-current generator, it is converted into current of pressure sufficiently low to meet the requirements of the car motors which it is intended to operate.

The operation of the system and the apparatus principally relating to it may be concisely described by a presentation of the following data: Both alternating-current transmission lines, and direct-current trolley lines are employed in this system. The pressure of the current which is generated at the power station is raised by the means of transformers to such point as is known to be least expensive in transmission over the line which is carried along on the trolley poles, and serves as a feeder to substations located along the line of interurban roads. The current as delivered to these interurban substations, which are usually located about ten miles apart, is of a pressure far too high for the safe operation of the motors, and in order that it may be reduced to a suitable pressure, each station is equipped with a set of transformers. The transmission pressure is reduced by these transformers, and the current then passes into an alternating-current motor, which is also a part of the substation equipment, and is connected to a direct-current generator which generates current at the required pressure of about 600 volts, which is suitable for the operation of the car motors, and at about this voltage the current is delivered through cables from the direct-current generator to the trolley, and is collected by the trolley wheels of the cars along the line of road.

This system of transmission is extensively used at the present time, and is the same on all lines using it, except for modifications here and there in the method of winding the armatures of the generator and motor. Where the armatures of these two machines are wound on the same core and employed in a single set of field magnets, the construction is much simplified, and some expense is saved, and to this method of construction the term "rotary converter" has been applied.

The three currents, which have been treated in the foregoing explanation, constitute the three different applications of the electric current as motive power, the primary and great factor in the operation of every electric railway line at the present time, and with a view that every railway operative may at least possess the necessary knowledge of the cardinal features of these three currents, this subject will be concluded by a concise summary for ready comprehension and committal to memory:

1. Current, which, when leaving the generator, flows only in one direction, is the distinctive feature of the DIRECT-CURRENT SYSTEM.

2. Current which alternates, or flows alternately, first in one direction and then in the other, is the distinctive feature of the ALTERNATING-CURRENT SYSTEM.

3. Current generated and transmitted by alternating current machinery, and applied for the operation of cars, by means of direct current apparatus, is the distinctive feature of the ALTERNATING-CURRENT-DIRECT-CURRENT SYSTEM.

SINGLE PHASE MOTOR. Less first cost and operating expenses, together with greater simplicity, are the characteristic advantages by which the single phase railway motor reaches the same results in the movement of cars as those obtained by the use of the direct-current equipment. By this system instead of the alternating current received from the generators, being converted into direct current by rotary converters, it is reduced in voltage by transformers, and supplied directly to the cars. This reduction in voltage is effected at the substations, and the equipment, not being complicated, requires only cursory supervision.

By the employment of a transformer on the car in connection with alternating current motors, any desired ratio may be obtained for the voltage of the trolley and that of the motors, whereas, with the direct current, it is necessary to supply power to the cars at the voltage of the motors. The alternating current may be transformed with great facility, which is generally considered a signal advantage in operation.

By the single phase system the heaviest work may be performed from an ordinary trolley wire, without extra feeders. The heaviest cars or trains may be operated with a very small current, as the system permits of the distribution of a large amount of power, a voltage of 11,000 being readily employed on a properly insulated trolley wire.

It is well known that, to reverse the current at the terminals of a series direct current motor does not reverse the direction of rotation, or interfere with the operation and, therefore, the principle involved in the single phase operation is nothing new, and the principle is absolute or unvarying regardless of how often the current may be reversed, hence the ordinary direct current railway motor must, or will rotate when proper alternating currents are used, as the effect of an alternating current is practically the same as the rapid and continuous reversal of a direct current.

With the single phase system, voltages of 3,300 and 11,000 may be employed, although the standard trolley voltage for operation is 6,600. Generally single phase motors are wound for 200 to 250 volts, whereas the direct current motors are wound for 500 to 550 volts, and for this reason greater brush capacity is required than with direct current motors, as the currents are larger, and to meet this variance a four-pole motor is generally equipped with four brush arms and a six-pole motor with six brush arms.

The speed of the single phase motor varies with the terminal voltage, the same as with direct current motors, and in this manner the motor is governed. Therefore, the reduction of the trolley voltage supplied at the motors must be provided for, and for this purpose an oil-insulated, self-cooling ''auto-transformer'' is employed. The changing of the motor grouping, however, is not required to obtain a variable voltage, although, as with direct-current motors, the speed of the single phase motor varies with its voltage at the terminals, and in this manner is governed. No resistance is required in the circuit, as it is only necessary to make connection with motors and the different auto-transformer taps.

With the proper voltage the single phase motor operates as efficiently on direct current, as on alternating current by reason of inherent qualities.

The advantage of the single phase motor under certain conditions of operation, is that it can handle cars over some sections of track with the same power by which direct current cars are operated, and then by connecting the single phase motors in series they can run from a low-voltage trolley wire as well as from one of high voltage.

ENCLOSED ARC HEADLIGHT EQUIPMENT FOR STREET RAILWAY SERVICE.

FORM B.

The equipment consists of two parts: the headlight, including cable, plug and two sockets; and the rheostat.

TO PREPARE HEADLIGHTS FOR INSTALLING.

When the headlights are received and unpacked, open the glass door and remove all shipping ties from the mechanism. Carefully brush out all dust, etc., that may have accumulated. Examine the mechanism for loosened parts.

INSTALLING THE SYSTEM.

Connections should be made according to the diagram (Fig. 58), with the rheostat installed in a vertical position where there is a free draft of air. Be sure that the car dasher is grounded to the negative side of the line. That the headlight may be interchangeable for either end of the car, each platform should be furnished with one of the sockets, to which the headlight can be attached as shown.

Where it is desired to use incandescent lamps in place of the resistance, and thus utilize for car lighting the power otherwise lost, lamps should be connected in multiple series so as to supply 4 amperes, and 80 volts to the headlight under average operating conditions.

ADJUSTING THE HEADLIGHT.

All equipments are carefully adjusted and tested before shipment. If the installation is made as above directed, no readjustment should be necessary. With the resistance in series with the headlight, and a 520 volt line there should be approximately 4 amperes 80 volts at the arc. The current is dependent upon the amount of resistance in circuit, and the arc voltage depends upon the arc length or, in other words, upon the position of the stop which limits the upward movement of the carbon clutch.

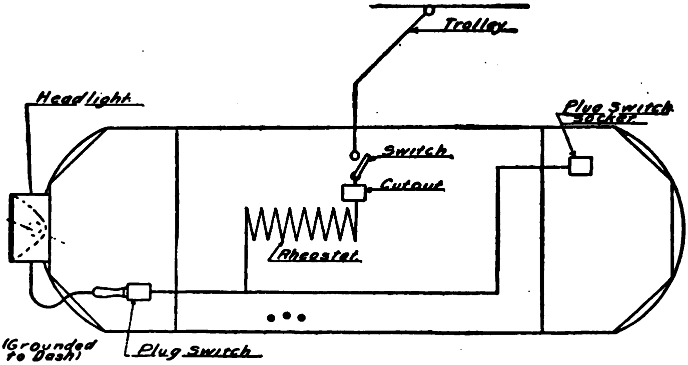

Fig. 58. Connections of Enclosed Arc Headlight Equipment for Street Railway Service, Form B.

The lower carbon should be raised slightly from time to time to keep the arc in focus.

CONNECTING.

Hang the headlight on the dasher and insert the plug in the socket. When properly connected in circuit the upper carbon is positive.

ENCLOSING GLOBE.

The headlight should never be used without the enclosing globe which excludes the air from the arc. The enclosing globe should be properly fitted at the bottom so as to make an air-tight joint. The upper edge of the globe must rest squarely against the cap. The number of hours the lamp will burn with one trimming depends largely upon keeping the globe tight and excluding the air.

REFLECTOR.

The reflector in front of the lamp mechanism is held in place by two screws. The inside surface should be kept clean and bright.

CARBONS.

Only the best grade of solid carbons of the following dimensions should be used:

Upper, 6″ long x 3/8″ diameter.
Lower, 4″ long x 3/8″ diameter.
Maximum allowable dia. of 3/8″ carbons .400″.
Minimum allowable dia. 3/8″ carbons .390″.

The total burning time of the above carbons should be about 24 hours.

TRIMMING THE HEADLIGHT.

As carbons vary somewhat in diameter, only those within the limits specified should be used. The carbons should pass freely through the enclosing globe cap, for any friction at this point will prevent the proper operation of the lamp. Be sure the carbons are smooth and straight.

To carbon the headlight, disconnect it from the circuit, and remove the lower carbon by opening the supporting spring at the bottom. The inner globe should be removed, cleaned and replaced, returning the holder to its proper position by bringing the top of the carbon to the focus of the reflector. Remove the cap on the top of the headlight and drop the upper carbon into the carbon tube. Replace the cap.

LESSON 7.

LIGHTNING ARRESTERS.

LOW VOLTAGE.

Question 1. What is the oldest form of arrester?

Answer. The saw tooth spark gap of the telegraph offices.

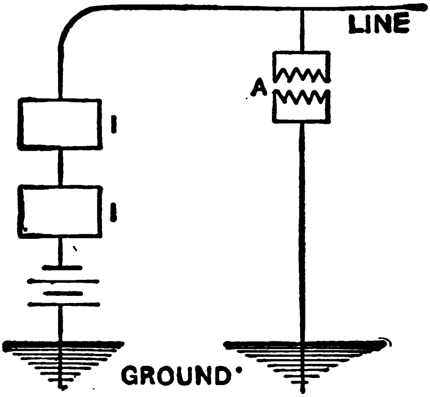

Fig. 59. The Saw-tooth Lightning Arrester as used on Telegraph Circuits. I and I are the Instruments and A the Arrester.

Question 2. Describe it.

Answer. Two brass plates with V-shaped points are set close to each other on an insulating base, one plate is connected to the line and the other to a ground plate buried in the earth. (See Fig. 59.)

Question 3. How does it operate?

Answer. The lightning being of an electrostatic nature discharges from points readily, and being of an enormous pressure is able to jump the air gap between the points. The telegraph instruments contain electro magnets whose coils act as choke coils.

The lightning has the choice of the path through the instrument coils or across the air gap. It practically always takes the air gap and runs to the earth through the ground wire.

Question 4. What objection is there to this type of arrester when power circuits are to be protected?

Answer. The spark caused by the lightning in leaping across the air gap forms a conducting path between the plates.

The pressure on the line due to the generators sends the current across this path which forms an arc melting the edges of the plates.

This arc grows larger until it conducts enough current to "blow"* the fuses in the circuit, which interrupts the service.

The arcing of an arrester is always caused by the current of the line following the sparks due to lightning discharge.

Question 5. What is the easiest way of stopping the working current from following the lightning discharge?

Answer. Place small fuses (as in Fig. 60) in the ground wires of the arresters before they join to the common† ground wire. Then any working current following the lightning discharge will blow these fuses instantly, leaving the main fuses unharmed. This will not interrupt the service.

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*Melt.

†A wire acting as a ground wire for several others is called a "common" ground wire.

Question 6. What is the objection to the arrangement?

Answer. Often the two fuses are blown, the arrester is useless and machinery left unprotected, there being no ground connection to conduct the discharge away.

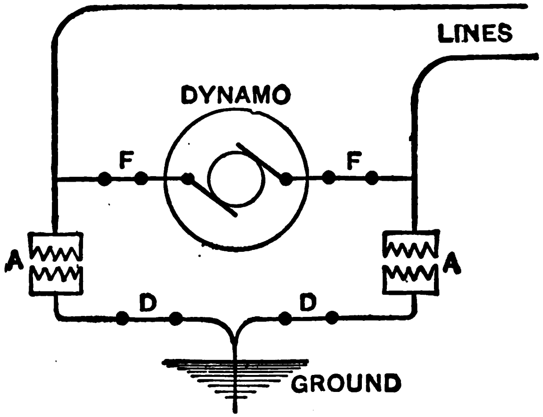

Fig. 60. The Saw-tooth arrester applied to a Dynamo. F, F are the regular fuses. D, D are the fuses for Arrester Circuit.

Question 7. But the fuses can be replaced?

Answer. Perhaps not before the next discharge has come. Moreover, a lightning arrester should allow the static charges which accumulate even in clear, dry weather to escape. These discharges sometimes snap across an arrester in the steady stream.

Question 8. What are some of the better ways of stopping the passage of the current after the discharge?

Answer. There are various ways, some methods put out the arc which is conducting the working current, and some try to prevent an arc or at least make arc very small.

Question 9. How is the arc put out?

Answer. By air blast, electromagnetic action, mechanisms for lengthening the gap momentarily as the discharge passes, also use of non-arcing metals.

Question 10. How are arcs prevented?

Answer. Smothering the arc so that it doesn't form for lack of air; insertion of resistance into the discharge circuit which weakens the current following discharge so that it cannot hold an arc.

Question 11. What should be done if an arrester in a station holds its arc?

Answer. The arc should be beaten out with a cloth or broom, or it should be smothered with sand.

Dry powder fire extinguishers are very useful for this purpose, but water or liquid extinguishers should never be used.

Question 12. Where should arresters be placed?

Answer. At the point where lines enter or leave any building, and at intervals along the line.

Question 13. Why should they be placed along the line? Will not the protectors at the buildings protect the machinery?

Answer. It seems to be generally believed now that lightning runs along the lines in waves and that at one point it may be so weak that it will not jump to ground through a certain arrester but pass on, and the same charge a few miles further on, will either be discharged through an arrester there or if there is no arrester, do considerable damage.

Hence all the most exposed places on the line should certainly have arresters and a few strung along the line will not be wasted.

Question 14. What is the best arrester?

Answer. Each kind has its good points, some will not work on low pressures, others will not stand the severe test of Rocky Mountain use, but are reasonable in price and satisfactory in action in the more open and level parts of the country.

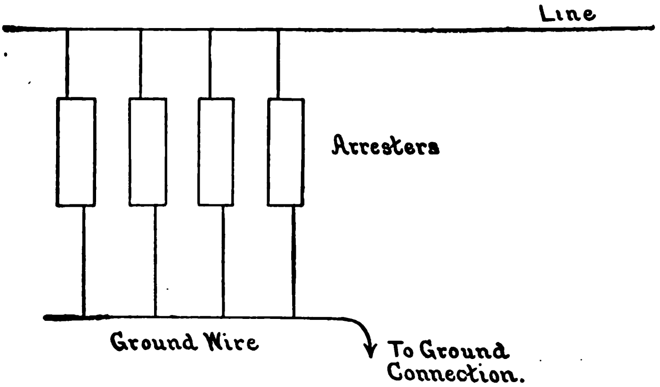

Fig. 61. Bank of Lightning Arresters.

Any arrester is hardly a complete protection unless combined with choke coils. (See Lesson 9.)

Question 15. Into what classes may arresters be divided as regards to the circuits and apparatus they protect?

Answer. (1) For use when currents are very small and voltages moderate as in telephone lines. The instruments are very delicate and need absolute protection.

(2) When currents are small and voltage moderate as in telegraph and signalling lines. Here the apparatus is heavier and less liable to damage.

(3) Power lines and lightning circuits where currents are heavy and voltage moderate, say up to 2500 volts.

(4) Power lines, transmission lines where the voltage is very high, say from 11000 up to 50000 or 60000 volts.

Question 16. Into what classes may arresters be divided as regards to the design of the arrester?

Answer. (1) Single gap arresters where one place is provided for the lightning to jump across.

Single gap arresters are often installed in banks in parallel* so that many places are provided at once.

The old saw tooth arrester is really a bank of single gaps.

(2) Multigap arresters, in which we have a number of single gaps in series.

These are sometimes simply a set of arresters in series. Each arrester being designed for say 2500 volts, using four in a series will protect a 10000 volt circuit.

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*The words series, parallel, and shunt will be more fully explained in Lesson 18, but it will be sufficient now to state that if a current goes through all of a number of instruments or resistances, they are in series. If the current splits and part goes through one set of instruments or resistances and the rest goes through another set then these two sets are in parallel.

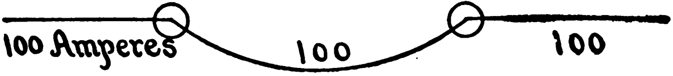
Each set while in parallel with the other set may of course consist of several pieces of apparatus in series.

When a circuit is cut and a new piece of apparatus is inserted, this piece is in series with the other.

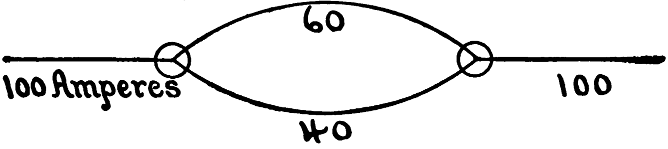
When a circuit has a new piece of apparatus attached by soldering on the wires without cutting the original circuit the new piece is a shunt circuit and the part of the old circuit is said to be shunted.

Usually they are so designed that a single arrester consists of a set of gaps in series. These arresters can be placed in series for high voltage.

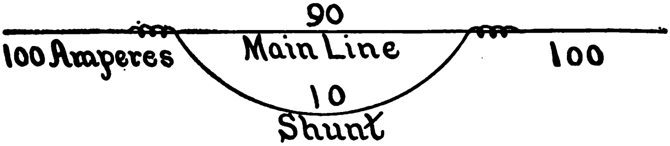
Series Circuit



Parallel Circuits



Short Circuit



The part of the main line which carries 90 amp. is shunted by the shunt which carries 10 amperes.

(3) Arresters with series resistances. The idea being that lightning will pass through the resistance without being obstructed much while the normal line pressure cannot send enough current through the resistance to hold an arc between the discharge points.

(4) Shunted resistances. In this type a resistance is put in parallel with the spark gaps. Experiment has shown that by proper design this is very effective in preventing an arc across the discharge points.

(5) Fixed gap length. In some arresters the gap length is fixed, and resistance (series or shunt), also, and the kind of metal used for the points, is used to suppress the arc.

(6) Lengthened gaps. The gap points are shaped like horns and the heat of the arc lengthens it by the uprush of hot air or the arc is forced up by magnetism.

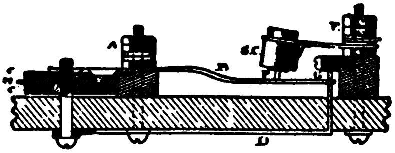


Fig. 62. **Lightning Arrester and Stray Current Protector for Telephone, Bell and Signalling Circuits.**

In other types the gap points are drawn apart by magnetism.

Question 17. What type of arrester is used for telephone circuits?

Answer. The protector is shown in Figs. 62 and 63. The line current enters at binding post A and passing along the spring B goes through the pin P through the wire of the coil SC on to post E, where the instrument wire is attached.

Each side of the apparatus is just alike, there being one piece for each line wire.

On the left of post A are two carbon blocks, C and C_1, separated by a slip of mica M with a circular hole in it. The upper carbon block has a drop of fusible metal let into its lower face, but it is flush with the carbon.

The upper block is in contact with post A by a spring which holds it in position. The lower block rests on a metal plate, which is connected to the ground wire D.

When lightning or any pressure over 300 volts comes on the line it jumps across the air gap between the carbon blocks (whose length is equal to the thickness of the mica strip) and goes to ground. It at the same time melts the drop of metal, making a complete ground. The instruments are then absolutely short circuited and protected.

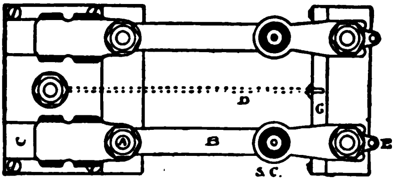


Fig. 63. Top view of Arrester shown in Fig. 62.

This means that there is a short and low resistance path for the current, which lightning will follow instead of going through the instruments.

Should there be a cross connection with other lines or a leak to the telephone line, the instruments could be damaged by the amount of current, while the pressure was far below 300 volts.

In this case the "sneak current," as it is called, goes from A along the german silver spring B, up through P and through the sneak coil SC.

The sneak coil is of very fine german silver wire, about 30 ohms resistance and in a few seconds this coil generates enough heat to melt a plug of fusible metal which holds the pin P in place.

The spring B then moves up and touches the ground strip G, thus grounding the line and protecting the instruments.

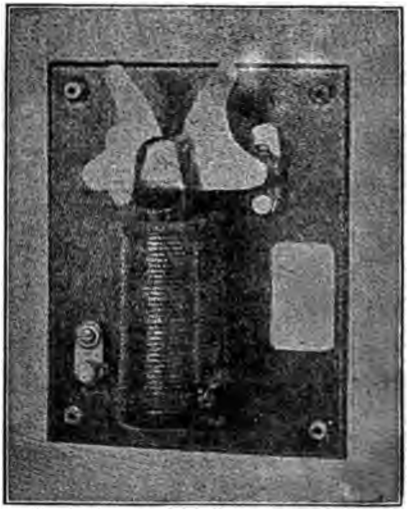


Fig. 64. Lightning Arrester with Magnetic Blow-out

Question 18. What type of arrester is used on moderate voltage lines?

Answer. One type is shown in Fig. 64. The air gap is between the curved plates. The magnet below is excited from the dynamo and the arc when formed is blown upwards until the space at the upper end of the curved plates is too long for the pressure to maintain the arc, The instrument acts as if the arc were blown out by a puff of wind.

Another form of this arrester has two flat plates so surrounded by the magnetism that the blow out effect is stronger, and it is relied on, there being no horns to help. Both of these are used on direct current circuits.

Question 19. Describe an arrester for alternating currents at moderate voltage.

Answer. There is a non-arcing arrester for A. C.* work. It consists of seven cylinders, each one inch in diameter and three inches high. They are made of white brass with a large percentage of zinc, and very little copper, in it. They are knurled or checkered so that the surface is covered with little points.

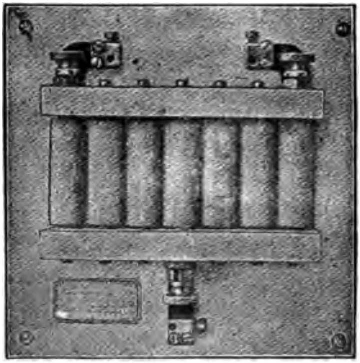


Fig. 65. Wurtz Non-arcing Lightning Arrester. Used with Alternating Current.

These cylinders are held in insulating strips so as to be about 1-64 of an inch apart. For low voltages the center cylinder is grounded and the end ones connected to the lines.

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*Abbreviation for alternating current.

When used on A C circuits the discharges which spark across do not cause arcs.

The probable reason is that the cylinders being close together, the spark makes a little explosion which blows the arc out, and the boiling of the metal where the spark jumps carries the heat away in the vapor and the spot is too cool to hold an arc.

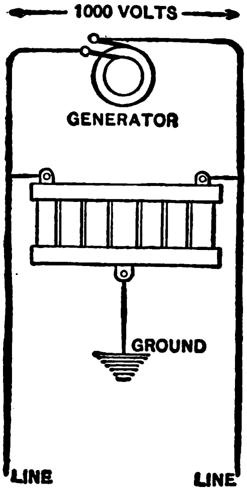


Fig. 66. Wiring diagram for 1000 volt circuits. One Arrester used.

The cylinders must be turned after each storm to present fresh surfaces for the next discharge.

A single arrester is shown in Figs. 65 and 66. Figs. 67 and 68 show the arrangements for higher voltages.

It will be noticed that this is of the multigap type.

[In Fig. 68 is shown the beginning of the "new idea" in lightning arresters which will be discussed at length further on.]

Question 20. How does the non-arcing arrester in Fig. 68 operate?

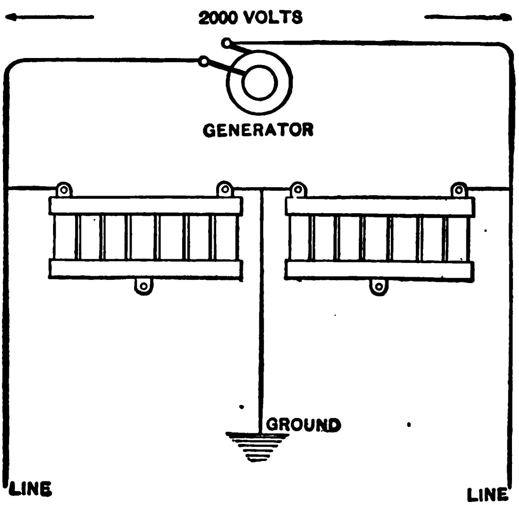


Fig. 67. Wiring diagram for 2000 volt circuits. Two Arresters used.

Answer. The operation of this arrester is as follows: The number of series gaps is adjusted to the voltage at which the arrester is desired to discharge. This is the real lightning discharger. The series resistance is small and so wound that it is as little like a coil in its choking action as possible. Its presence will prevent a large current flowing through the arrester while it is discharging.

If only as few series gaps as are shown were there, with a small series resistance, the dynamo current which follows the lightning discharge will cause an arc and burn the cylinders.

When shunted gaps are used the result is:

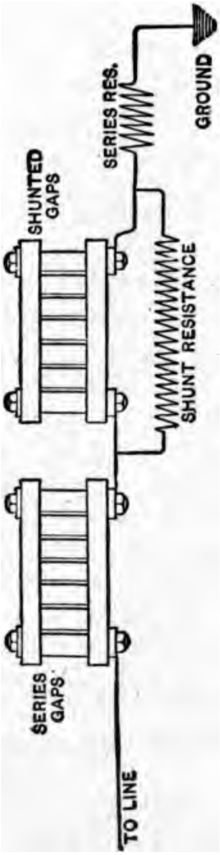


Fig. 68. Arrangement of Arresters and Resistances for High Voltages. This forms a Multigap Arrester.

The lightning followed by the line current passes through the series gaps. Then the lightning due to the choking action of the shunt resistance, sparks through the shunted gaps, while the line current on account of the high resistance of the shunted gaps, passes through the shunt resistance.

There is then no line current in the shunted gaps to hold an arc. The lightning having now discharged the line current finds a series circuit, composed of the series gaps, the shunt resistance and the series resistance.

The shunt resistance being large, the total resistance of the arrester is large enough to shut off the line current entirely.

Had such a large resistance been in series with the series gaps at first the arrester would not have started to discharge and of course afforded no protection.

Question 21. Is there a non-arcing direct current arrester?

Answer. Yes, the non arcing direct current arrester is based on these facts.

(1) Lightning will pass over a non-conducting surface more readily than across an equal air gap.

(2) It will pass even more readily if the surface is covered with carbon.

(3) An arc cannot form where there is no air to help the material burn.

A lignum-vitæ block is charred in its center for about half an inch in width. Two metal plates are set flush in the block on each side of the charred strip.

A second block is screwed tightly over the first to keep out the air.

This arrester works on direct current up to 700 volts. The lightning passes easily from plate to plate; while the charred strip of about 50000 ohms resistance prevents the passage of current from the line.

The lightning cannot start an arc in this small space.

One plate is connected to a line wire and the other to the ground. Two should be used, one on positive wire and the other on the negative.

These arresters have been used with "smooth cored" alternating current generators furnishing 1000 volts pressure.

Question 22. Is there a small, cheap arrester for single instruments and small buildings, as switch men's cabins, tool houses, etc., and for use on electric light circuits?

Answer. Yes. A lightning arrester designed for alternating current (abbreviated A. C.) up to 350 volts pressure is shown in Fig. 69.

Where long secondaries are run from transformers, a necessity has been found for the use of lightning arresters. The demand for a low priced but effective and reliable arrester for this service has resulted in the arrester shown.

This device is for use on any A. C. circuit of 350 volts or less, and is suitable for protection of individual series A. C. arc lamps, as well as on incandescent lighting circuits. Its effectiveness when placed on wires at the entrance to buildings, store-houses, signal towers, etc., recommends its general adoption.

A detailed description of construction is given later. The general plan is shown in Fig. 69, where will be seen the two large circular discharge plates separated by an air-space of 1/50 (.020) inch at their beaded edges. Over this air-gap a heavy discharge may pass, while light discharges and static surges will pass to earth, more slowly, through the high resistance disc that separates the larger metallic discs. This disc is of permanent resistance and allows the passage of but an infinitesimal normal current, while permitting the escape of the high voltage static discharges. In the event of the discharge being heavy, it will jump the spark gap, but the low voltage of the normal current will not maintain an arc, owing to the cooling effect of the heavily beaded disc.

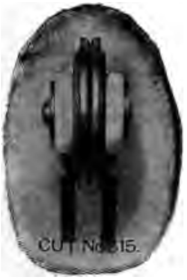


Fig. 69. Small Arrester for Alternating Current up to 350 volts. Fixed gap type.

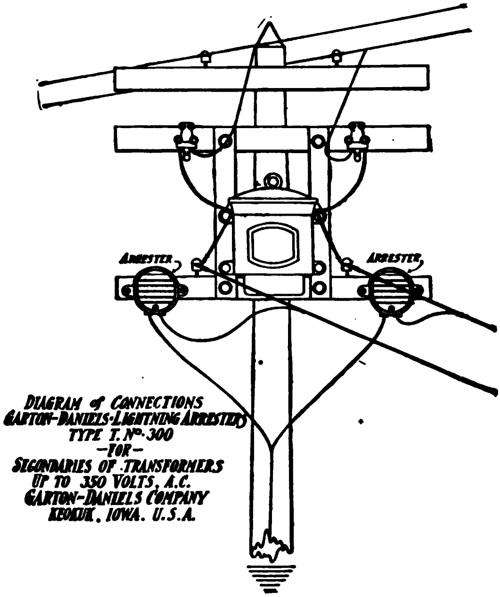


Fig. 70.

It will be seen that this device offers a choice of either of two paths, one highly efficient as an outlet for static surges, and the other (the spark-gap of 1/50 inch) a highly efficient path for lightning discharges.

When used on the secondaries of transformers, one arrester is necessary on each leg of the circuit. Same should be connected in a shunt path to earth as shown in Fig. 70.

As an arc lamp protector it is connected directly across the terminals of the lamp as shown in Fig. 71, thus offering a path around the lamp, to the standard pole arresters, which should be distributed along the line at intervals. These standard pole arresters are, of course. connected between line and ground, and thus offer an easy escape for the discharges.

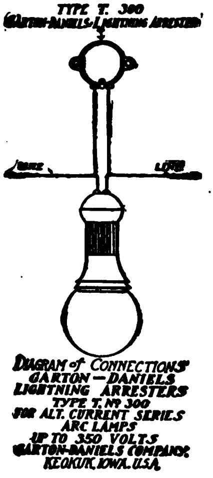


Fig. 71.

It has been customary in many cases to use standard forms of arresters in the same service for which this device is designed. These standard forms have the objection of higher cost, larger size, and, as all employ a much greater spark-gap distance, are not nearly so efficient as this Type T. arrester. Furthermore, the auxiliary path through the high resistance disc increases the efficiency of this arrester many times.

The device consists of the parts illustrated in Fig. 72 assembled as shown in side view Fig. 69. Parts Nos. 309 are two metallic discs, formed with a heavy bead around the circumference, the center being flat to make contact with the high resistance disc, No. 311. These parts are assembled on the insulating tube, 312. The high resistance disc separates the metallic discs so that the heavy beaded circles are separated by 1/50 (.020) inch. Parts Nos. 308 are insulating discs, also mounted on 312. The screw, No. 306, passes through steel washer, 307, tube, 312, and asbestos disc, 313, so as to clamp them together when screwed into weather-proof box, 302. The flexible leads, No. 310, pass through porcelain insulator, No.

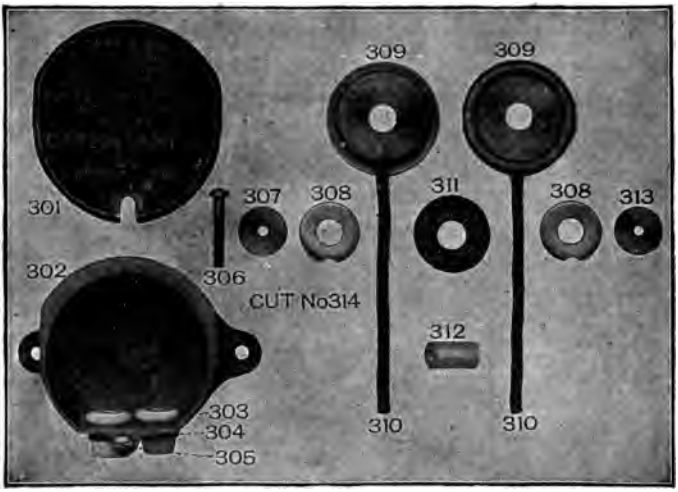


Fig. 72. Parts of Arrester shown in Fig. 69.

303. The cover, 301, hooks over the top of box, 302, and is fastened in place by but one screw, 305. This cover is perfectly weather-proof. Complete, the arrester measures 3½ inches from center to center of supporting holes.

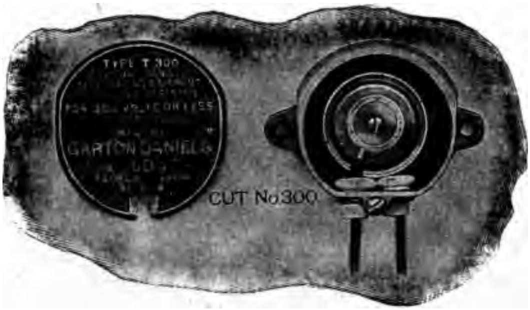


Fig. 73. **Arrester parts as shown in 72. assembled ready to screw cover on.**

PROTECTION OF LINES.

Question 23. How should signal lines be protected?

Answer. When on pole lines an arrester should be placed on pole about every half mile; when run in conduits or tunnels one should be placed at each end of conduit or tunnel.

Question 24. How should telegraph lines be protected?

Answer. As the instruments are only placed in stations, an arrester at point where wires enter station is sufficient.

Question 25. How should telephone lines be protected?

Answer. A protector which contains a "sneak current" device should be placed in every line where it enters a building.

Question 26. How should feeders to trolley wire or third rail be protected?

Answer. Such lines are usually fairly short and not much exposed to lightning being carried on low poles. The arrester on the feeder at the station and one where the feeder connects to trolley or third rail should give ample protection.

Question 27. How should trolley wires or third rails be protected?

Answer. The arresters at the ends of the feeders ought to be sufficient for the trolley wire also.

If there are very few feeders it would be well to see that there is an arrester every half or three quarters of a mile. One to the mile will do, as trolley construction is very strong and not liable to damage.

The third rail lies along the ground and is seldom struck. If it were the mechanical strength of the rail itself and its insulators would protect them, although the lightning did side flash to the ground.

Question 28. What protection should motor cars or locomotives have?

Answer. There should be an arrester in the main circuits which furnish the power, and an arrester in the control circuits which control the motors. These two arresters should be of different styles. That for power circuits should discharge at 1,000 volts and that in the control circuits at 250 volts.

Question 29. What protection should be given to a trolley car?

Answer. An arrester should be placed on roof or under hood of such a capacity that there can be no chance of its failing to operate.

MOTOR ARMATURES.

Question 1. Is there any difference between the armature of motors and dynamos?

Answer. Theoretically there is no difference between the armature of a dynamo and motor. In fact, many machines are placed in conditions in which their functions change, perhaps a hundred times per day, from that of generator to that of motor.

Question 2. Are there any special provisions necessary to make them operate thus?

Answer. No. This change takes place automatically, and the operation is so smooth that the observer will have no idea in which capacity the machine may be operating from moment to moment. It is also no unusual thing for a dynamo working in parallel with other generators to become reversed, and instead of delivering current to the line to be drawing from it and running as a motor.

Question 3. What should one principally have in view in the design of a motor armature?

Answer. Motor armatures must be designed to produce a certain counter E. M. F. just as dynamo armatures are designed to produce E. M. F. In the case of a dynamo the power is measured by the product of the E. M. F. and the current, so in the motor the power is proportional to the product of the counter E. M. F. and the current.

Question 4. How do you proceed to calculate the winding for a motor armature?

Answer. We proceed in the same way as with dynamos, but we must never figure on quite as high an E. M. F. as with the former. The current passing through a direct current motor is equal to $\frac{V-v}{R}$ where V is the voltage of the line that supplies it; v the counter E. M. F. of the armature, and R its resistance.

It can be readily seen that in order to get more power out of a given motor, its counter E. M. F. must fall, so that a greater current can flow.

Question 5. How is this brought about?

Answer. In the case of a motor which is in operation this counter E. M. F. is reduced when the speed reduces, on account of a heavier load coming onto the motor. This allows more current to flow until the power of the motor becomes equal to the task imposed upon it. If we should ask more of the motor than it can give, it would take too much current, and burn out the armature.

If, however, we wish to design a motor that is to operate at some exact speed, we must take these facts into consideration, and the wires must be so chosen that when running at the required speed they will generate the counter E. M. F. necessary.

We may take for the purpose of illustration the same armature we had in consideration in the previous section. We found in this case that we required a wire which would give us 11 turns per inch; this corresponds to a No. 12 wire. Such a wire is capable of carrying 14.3 amperes. To wind this armature 8″x8″ with this wire will require about 770 feet. This quantity of No. 12 will have a resistance of 1.39 ohms. We have, however, only half of this on one side, and only 14.3 amperes pass on one side, so that the total E. M. F. to drive this current through the armature is 14.3 × .697, which is 9.96. In order that this motor may allow the 14.3 amperes to pass, its counter E. M. F. must fall to 9.96 volts less than the E. M. F. of the line. If this is 110, the speed must slack off about 9% in order that the motor may develop its full power.

It is easily seen from this that, in order that the motor may operate at a fairly constant speed, the resistance of the armature should be made as low as possible. In practice it is generally made so low that a reduction of 1% in speed will bring about the required lowering of counter E. M. F. to cause the proper current to flow.

ARMATURE TROUBLES.

Question 1. How do armature troubles manifest themselves?

Answer. Generally either by excessive sparking at the commutator, or by abnormal heating of the armature.

Question 2. What are the causes of such troubles?

Answer. They may result from any one of the following causes: There may be a wrong connection of one or more of the coils. Some of the coils may be grounded. There may be an open circuit. There may be a short circuit. The brushes may be improperly set. The brushes may not make sufficient contact with the commutator. The commutator may be rough or worn. The fields may be of uneven strength.

Question 3. How can a wrong connection of the coils be tested for?

Answer. In order to see how this test can be made let us consider Figure 74 for a moment. This figure shows the wiring of an armature connected to the commutator segments exactly as it would be if it were taken off, and the coils separated without detaching from the commutator, instead of being placed in an orderly manner upon the core of the armature. In other words, the connections are exactly as in an armature. If we should now take the two wires of some supply of current capable of delivering a few amperes, and connect these two wires to two adjacent commutator segments, as shown at *a*, and *b*, it is clear that current would flow through the coil connected between these two sections, and also through the other coils. The current has two paths: one through the single coil, the other through the remaining seven coils in series. The current in the two coils flows in opposite directions, with the result that a field of force is set up in the vicinity of the single coil. A suitable galvanometer placed at this point will be deflected in a certain direction. If we now revolve the armature and make

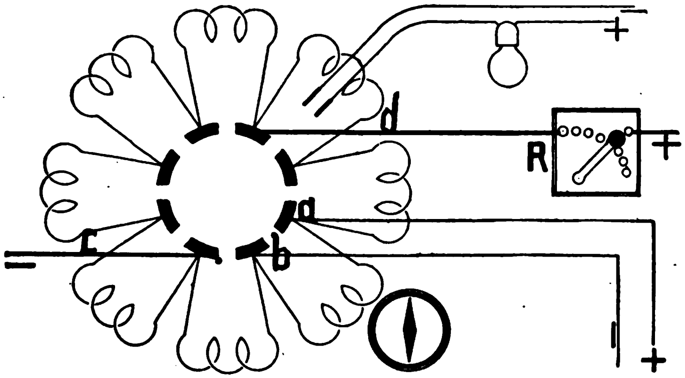


Fig. 74.

this test on each succeeding pair of commutator sections we will obtain a number of deflections of the galvanometer needle. If all the coils are correctly connected, the various deflections will all be in the same direction. If one of the armature coils is wrongly connected a different deflection will be obtained. In case one of the coils has been wound on in the wrong direction, it is not necessary to rewind it; the connections can simply be reversed.

Question 4. What is meant by a ground?

Answer. By a "ground" we mean an electrical connection between some current carrying part of the armature, and the metal armature frame. A "ground" is often caused by the insulating covering of the wire breaking down, thus allowing the wire to come in contact with the iron core.

Question 5. How do you test for this condition?

Answer. The simplest method of testing for a ground consists in taking a lamp or voltmeter and connecting it as shown in Figure 74.

Place one of the wires in contact with the iron core, and the other in contact with the wire on the armature. If the lamp lights, there is a connection between the wire and the core, and this should be removed.

Question 6. How is an open circuit located?

Answer. To explain this we again refer to Figure 74. Make connections to the commutator, as shown by the horizontal lines c d, to some source of supply. A rheostat should be provided, so that the current strength can be adjusted until a suitable deflection is obtained between adjacent commutator segments. Now take the two wires of the voltmeter and test the voltage between the various adjacent commutator segments. A reading will be obtained between each two segments on one side of the commutator, but on the side which contains the open coil no reading will be obtained until connection is made between the two segments to which the open coil is connected. At this point the voltmeter will show practically the full voltage of the supply current.

Question 7. How do you locate a short circuit?

Answer. If the short circuit has come on while the armature was in use, it will locate itself by a burned out coil. To test a new armature for short circuits we can proceed in the same way as for open circuit, the only difference being that, when we come to the short circuited coil we shall obtain either none, or at least a reduced deflection.

Question 8. What effect does an improper location of the brushes have?

Answer. An improper location of the brushes will manifest itself by a more or less severe sparking. If the brushes are of the right dimensions the trouble can be remedied by simply shifting them to the proper location, which is that of least sparking. Brushes should be of such length, and set at such an angle, that they come in contact with diametrically opposite points on the commutator, with all bi-polar machines.

Question 9. How must the brushes be set in connection with multipolar machines?

Answer. This depends on the manner in which the armature is wound. With a lap winding there are as many brushes as there are pole pieces, and they must be equally spaced around the periphery of the commutator. Provision must also be made so that they can be shifted to the point of least sparking. In wave wound armatures there may be only two brushes, these being so spaced that they are separated by an angle equal to the angle of separation of two adjacent pole pieces; for instance, with a four pole field they would be separated by an angle of 90°.

Question 10. Is much shifting of the brushes necessary?

Answer. This depends very much on the design of the machine. With some of the older machines constant shifting of the brushes is required with changes in the load, but with the newer, and better machines this is reduced to a minimum.

Question 11. What is the customary size of carbon brushes?

Answer. A carbon brush should be of such size that not more than 25 to 40 amperes per square inch of carbon are ever called upon to flow through it. It should have a firm bearing on the commutator, and should be light enough to accommodate itself quickly to any unevenness in the commutator. The commutator should be kept as smooth as possible and should not be allowed to wear unevenly.

Question 12. How does inequality in field strength affect an armature?

Answer. Wherever this exists there will be more lines of force cut by the armature on one side than on the other. This will cause a higher potential to be generated on one side than the other. The brushes will have to be set uneven distances apart, around the armature, and useless currents will be set up in the armature windings which will not only cause a loss of power, but which will unnecessarily heat the armature.

SPRAGUE—GENERAL ELECTRIC TYPE M—CONTROLLER.

GENERAL DESCRIPTION.

Fundamentally, the system comprises a set of electrically operated switches on each motor car with heavy contacts for handling the motor current; and small "master controllers" on the car platforms which admit current to control wires leading to the operating coils of the electrically operated switches or "contactors," and "reverser," as they are called. For train operation, suitable cable couplers are used to connect corresponding control wires together on all motor cars, so that when these wires are energized by any master controller, similar results are obtained simultaneously on all motor cars in the train.

The list of apparatus comprising a complete type M control is as follows:

2	Master Controllers.
2	Master Controller Switches with Fuses.
1	Control Cut-out Switch.
1	Set Control Fuses.
2	Control Connection Boxes.
1	Set Control Coupler Sockets.
1	Control Jumper.
1	Set of Contactors Wired in Box with Rheostat Tubes.
1	Reverser in Box.
1	Electrically Operated Circuit Breaker in Box.
2	Circuit Breaker Control Switches.
	Necessary Control Cable.

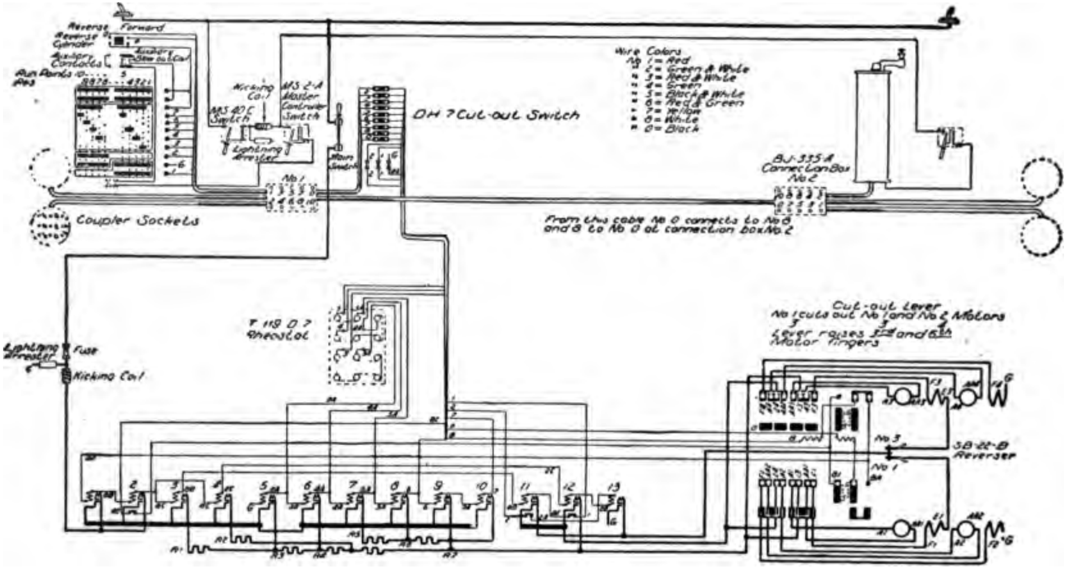


Fig. 75. Wiring Diagram for Four Motors with Hand Control. C-6 Master Controller.

By referring to various illustrations on the following pages the relative location and functions of apparatus will be seen for different types of equipments.

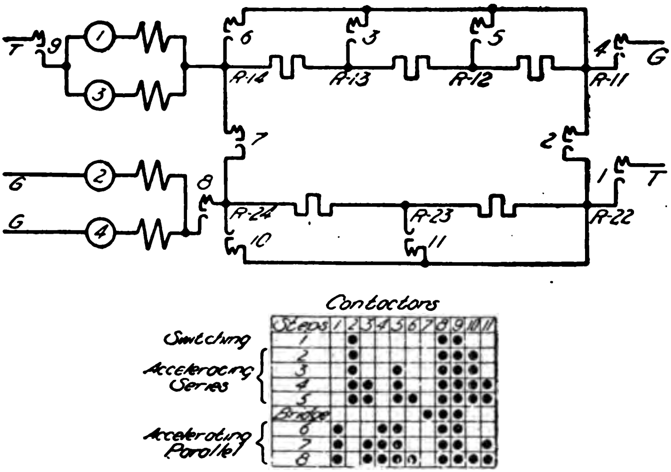
In addition to the control listed above, a complete car equipment includes:

Current Collectors.
Main Switch.
Main Fuse.
Lightning Arresters with choke coils (When used on trolley system).
Cast Grid Motor Rheostats.
Main and Motor Wiring.
Lighting Material.

At the present time there are four general forms of type M control in use. These differ only in their method of operation, and in details of apparatus, and may be classified as follows:

1 Hand or Non-automatic.
2. Semi-automatic.
3. Automatic Master Controller.
4. Relay Automatic.

On a large number of roads using the C-6 master controller the equipment shown in Fig. 75 has been standardized. This controller opens the motor circuit between series and parallel, as in the L type cylinder controller, but all present standard controllers operate on the "bridge" principle which keeps full current on all motors throughout the acceleration period. The bridge connections shown in Fig. 76 apply to all forms of control.



Contactors

	Steps	1	2	3	4	5	6	7	8	9	10	11
Switching	1		●						●	●		
Accelerating Series	2		●						●	●	●	
	3		●			●			●	●	●	
	4		●	●		●			●	●	●	●
	5		●	●		●	●		●	●	●	●
	Bridge							●	●	●		
Accelerating Parallel	6	●			●	●			●	●		
	7	●		●	●	●			●	●		●
	8	●		●	●	●	●		●	●	●	●

Fig. 76. Motor Circuits, Bridge Control.

HAND OR NON-AUTOMATIC CONTROL.

Referring to Fig. 77 it will be seen that the operating current for the contactors passes directly from the master controller through the multiple conductor control cables to the operating coils. Certain interlocks are introduced to prevent wrong operation, but in general characteristics the master controller is very similar to the ordinary cylinder controller. On the controller dial plate the successive resistances and running points are indicated. As the motorman moves the controller handle from point to point, the corresponding connections in the motor circuits are immediately produced.

There are two distinct circuits, commonly known as Control and Motor, both fed from either the trolley or third rail, as the case may be. The control circuit cor-

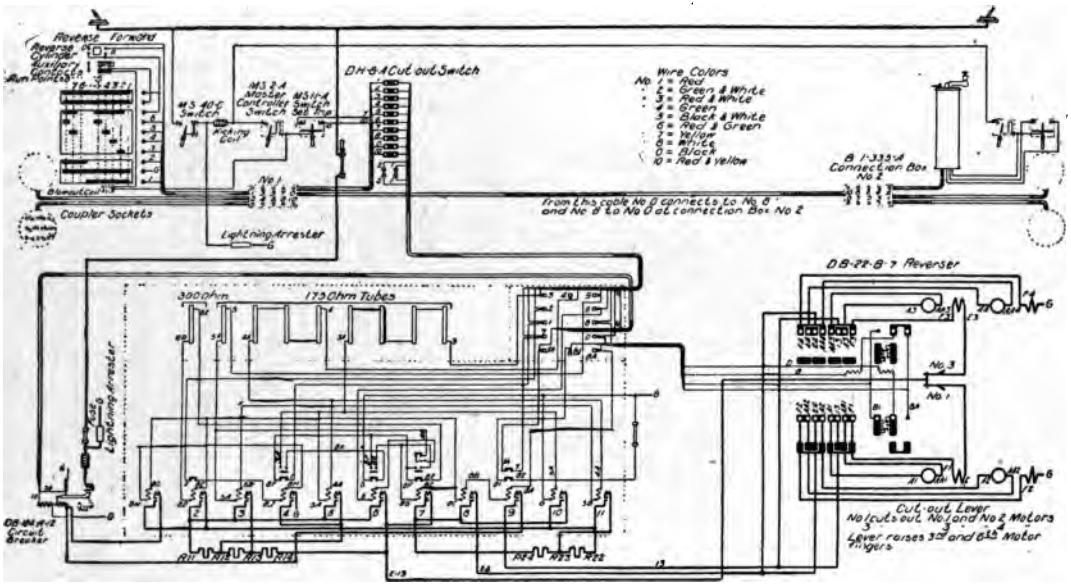


Fig. 77. Wiring Diagram for Four Motors with Hand Control and Bridge Connections.

responding to Fig. 77, is shown in Fig. 78. The path is from the trolley through the lightning arrester switch, kicking coil and master controller switch to the master controller. When either of the master controllers is operated, current passes through the proper wires into the multiple conductor cables to the connection box and thence through the control cut-out switch to the contactor box, reverser and circuit breaker. If the car is coupled in train with other motor cars, current also passes through the multiple conductor control cables to the coupler sockets, and through the coupler jumper to the next car, where part of it branches off through the control cut-out switch to the contactor box, reverser and circuit breaker on that car; and the remaining current passes on to the next car, and so on.

The control circuits in detail are shown in Fig. 78 and the motor circuits in Fig. 79. The path is from the trolley through the main switch, main fuse, kicking coil, through the circuit breaker to the contactor box. As the contactors close in their proper sequence, the current passes out through the cast grid rheostats and reverser to the motors and thence to ground.

SEMI-AUTOMATIC CONTROL.

This type of control is confined almost exclusively to locomotive service, where it is essential that the control shall be of the simplest possible nature and where also some safeguard is required to prevent slipping, the wheels or unnecessarily loading the system. It differs from the Hand or Non-Automatic Control, in that the master controller is provided with a centrifugal friction governor

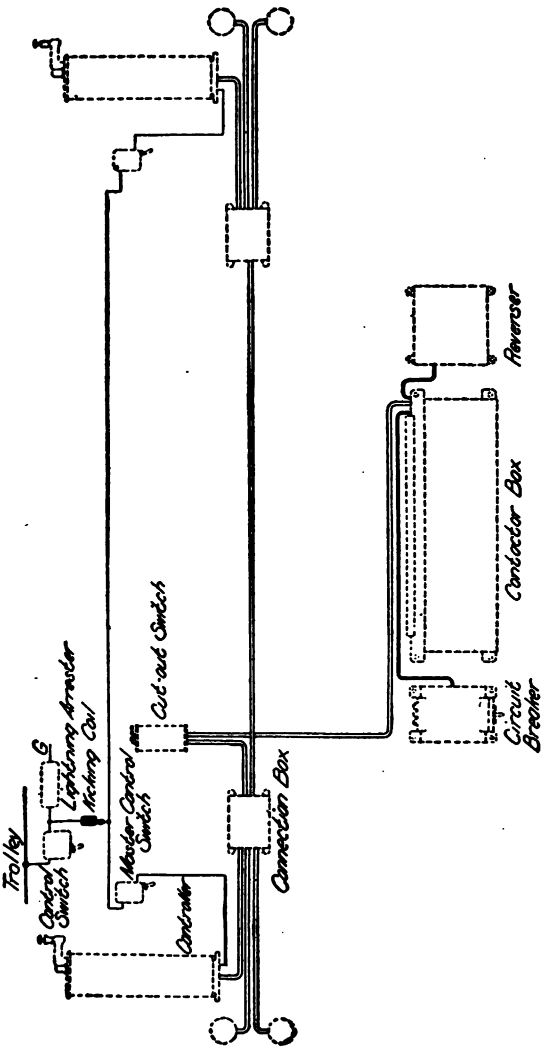


Fig. 78. Control Wiring.

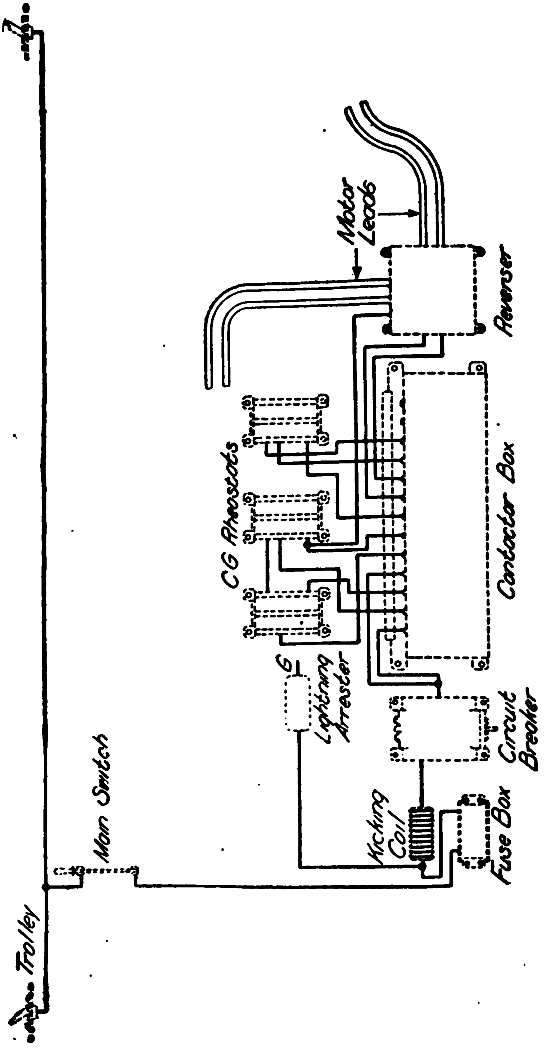


Fig. 79. Motor Wiring.

which has an electro-magnetic lock. The coil for this lock is energized through the contacts of a current limit relay whose operating coil is connected in series with the motor circuit. This relay can be adjusted so that it will drop out at a predetermined current value after it has picked up.

The governor prevents the controller being turned on faster than a predetermined speed, so that the relay has time to act. On each step of the controller the relay closes, admitting current to the locking coil. This prevents the controller from being moved further until the motors have accelerated and the current value decreased to the predetermined amount, when the relay opens and releases the lock on the controller, allowing the motorman to take the next step. From this it will be seen that if the motorman retains constant pressure on the controller handle, he will practically obtain an automatic acceleration. Fig. 80 shows a typical equipment of this kind.

AUTOMATIC MASTER CONTROLLER.

Automatic control is desirable for several reasons: First, to prevent abuse of the equipment through too rapid acceleration, and secondly to obtain the most efficient operation by accelerating as closely as possible to the slipping point of the wheels. In the automatic master controller equipment, the master controller is provided with a heavy driving spring, geared to the cylinder. Otherwise, it is practically the same as the master controller for the semi-automatic equipment, and has the same type of governor and locking coil. The same type of relay is also used in the motor circuit. This control may be used on equipments of all sizes and the general characteristics are identical with those of the "Hand" or "Non-Automatic" equipment. Fig. 80 shows the wiring for a typical equipment.

In service the motorman throws the handle of the master controller directly to the point corresponding to the speed required. This winds up the driving spring and starts the controller cylinder, which is limited in speed by the governor. The relay closes on each step due to the increase in current, and locks the controller until the current has decreased to a predetermined value, as in the "Semi-Automatic" equipment. With properly proportioned rheostats the current should rise to the same maximum value on each step, and decrease to the same minimum value before the relay opens and allows the cylinder to proceed. By adjusting the relay to drop out at the proper minimum current, a uniform acceleration may be obtained at any average below the limit of the motor capacity. The automatic master controller is so arranged that the driving spring may be readily disconnected by turning a key in the master controller. This changes the equipment to the "Semi-Automatic" type, since both the governor and relay are still active. The master controller is also provided with a device which permits cutting out the governor when necessary, thus reducing the equipment to "Hand" or "Non-Automatic" control.

RELAY AUTOMATIC CONTROL.

The results obtained in the Relay Automatic Control are practically identical with those in the Automatic Master Controller Equipment, but are produced in a

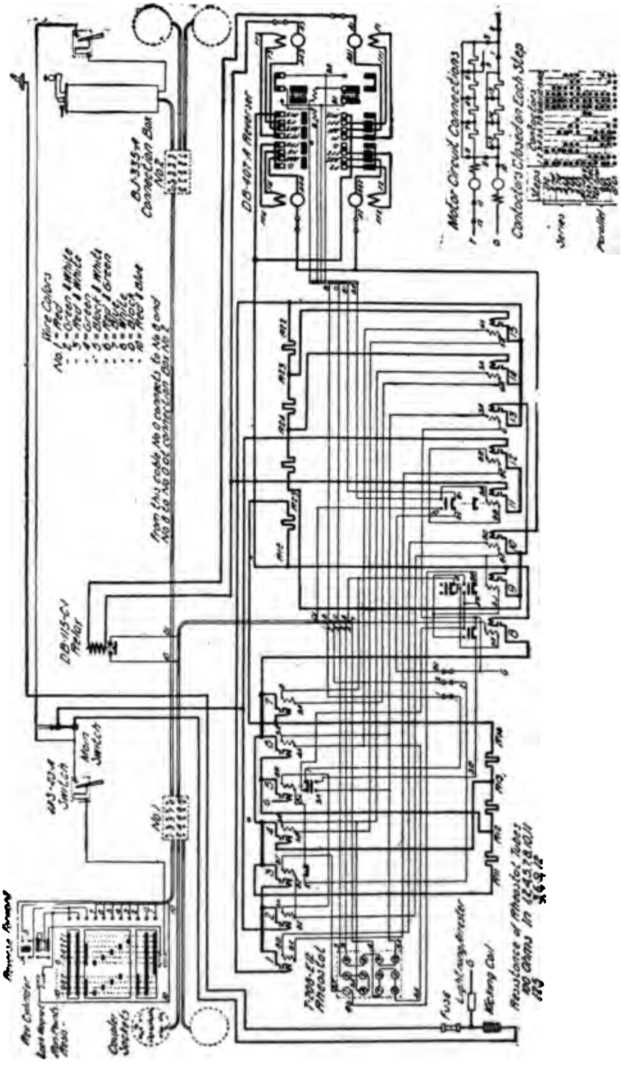

DB-407-A Reverser
BJ-335-A Connection Box No. 2
Wire Colors
From this cable No. 0 connects to No. 8 and No. 8 to No. 0 at Connection Box No. 2
DB-115-C1 Relay
Main Switch
No. 1
T-300-E2 Rheostat
Motor Circuit Connections
Contactors Closed on Each Step
Series
Parallel
Fuse
Lightning Arrester
Kicking Coil
Resistance of Rheostat Tubes

Fig. 80. Wiring Diagram for Four Motors with Automatic Master Controller and Bridge Connections.

different manner. In the latter the automatic features are confined to a more or less complicated master controller, the control circuits being practically identical with those in the Non-Automatic Equipment. In the Relay Automatic Control the master controller is small and simple in construction, and has five points on the dial plate, viz: Off, Switching, Series, First Parallel and Parallel. The functions of the different wires in the multiple conductor control cable are entirely different from those in the other equipments. Five wires are used for the control proper and two for the circuit breakers, as follows:

1 Actuating.
2 Retaining.
3 Parallel.
4 Forward.
5 Backward.
6 Circuit breaker, Set.
7 Circuit breaker, Trip.

Wires No. 4 and No. 5, are used for operating the reverser to give the desired direction of movement to the car. After the reverser is thrown to the desired position, current either through No. 4 or No. 5 wire holds the reverser in position and picks up the line contactors.

Fig. 81 shows the wiring for a typical Relay Automatic Control equipment from which it will be seen that the contactors are provided with numerous interlocks. Certain of these interlocks are used to insure against wrong operation of the contactors, and the remainder make the proper connections in the control circuit during acceleration. When the master controller is turned on, No. 2 wire energizes the Series contactor and passes through a number of rheostat tubes to ground. This is the retaining circuit. A current limit relay, designated on the plate as DB 112-B relay, is used to govern the rate

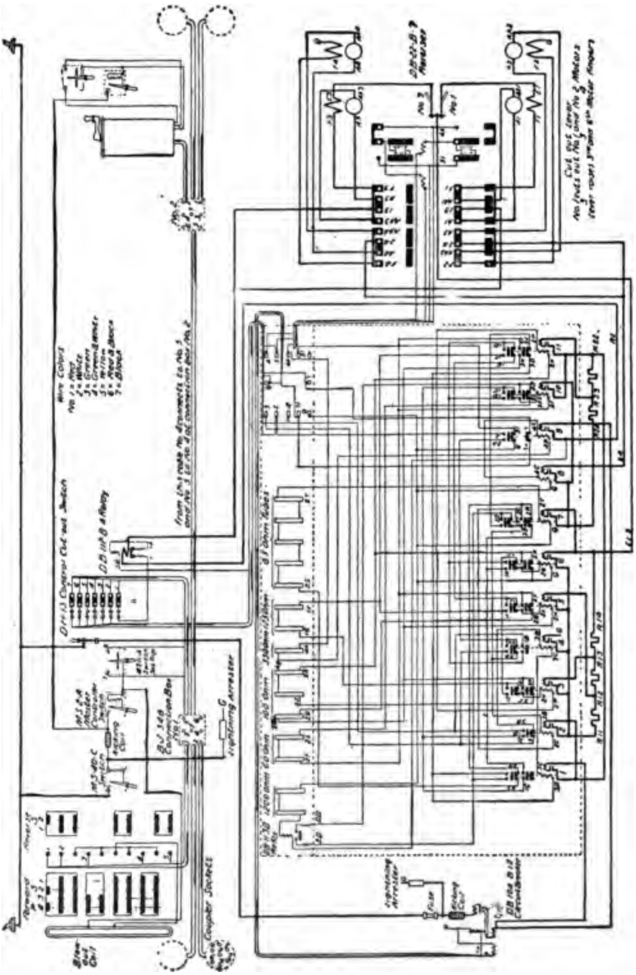


Fig. 81. Wiring Diagram for Four Motors with Relay Automatic Control and Bridge Connections.

of acceleration, this rate being determined by the current value at which the relay series coil will allow its plunger to drop. The scheme of operation consists in No. 1 wire being energized by the master controller, thus allowing current to pass through the contacts and shunt coil of the current limit relay, and through the interlock contacts to the coil of the first resistance contactor. This contactor then closes and by means of its interlocks cuts its coil into the No. 2 circuit in place of a resistance tube. No. 2 wire then holds this contactor closed. The current limit relay closes at the same time as the contactor, due to current passing through the shunt coil, and is held closed by motor current passing through its series coil. When the motor current decreases to a predetermined value, the series coil of the relay allows the plunger to drop and close the contacts. The interlocks on the last preceding closed contactor complete the No. 1 circuit through the coil of the succeeding contactor. The latter closes and by means of its interlock the coil is cut into No. 2 circuit. This operation is repeated until full series position is reached when the No. 1 wire picks up the bridge contactor.

If the master controller handle is in the parallel position No. 3 wire is energized, the transfer is made from bridge to parallel, and the rheostat contactors are again closed as in the series acceleration.

The control is so arranged that at any point during acceleration the existing conditions may be retained by moving the controller handle back to the switching point if the motors are still in series, or to the first parallel if the motors are in parallel. Step by step acceleration can thus be obtained through series by moving the controller handle to series and immediately returning it to the switching point. In the parallel position this is done by moving the handle to full parallel and immediately returning it to first parallel. Each time this movement is repeated, a step of resistance is cut out. Thus, the motorman can always obtain step by step, acceleration, but the acceleration cannot exceed the predetermined rate.

With this equipment a potential relay, designated on the plate as DB-113 relay is used. It will be noted that with this type of control the acceleration is local to each car, so that if current is momentarily cut off from a car in crossing a gap, the control locally returns to the off position, since the potential relay on that car opens and breaks the retaining circuit. When current is restored this relay closes, and the control automatically notches up to a position corresponding to the master controller handle on the car on which the motorman is operating.

MASTER CONTROLLER.

The master controller most commonly used for non-automatic control (Fig. 82) is similar to, but smaller than the ordinary cylinder controller of the K type. A separate reversing handle is provided, mechanically interlocked with the operating handle, so that reverse connections can be made only when the operating handle is in off position. This type of controller is designed to occupy the least possible space in the cab, and may be mounted with its back against the vertical partition, as the operating handle is connected to the cylinder through gears which give a full revolution of the cylinder for a 180 degrees movement of the handle. The amount of current handled by the master controller is small, viz: about two amperes for each motor car in the train. Consequently, the parts are light and are subjected to very little burning. The maintenance is exceedingly small and inspection is only required to insure proper contact of the fingers. All contacts are provided with an efficient magnetic blow-out, and auxiliary contacts interrupt the supply of current to the controller when the motorman removes his hand from the controller handle. A button is provided in the handle for this purpose which must

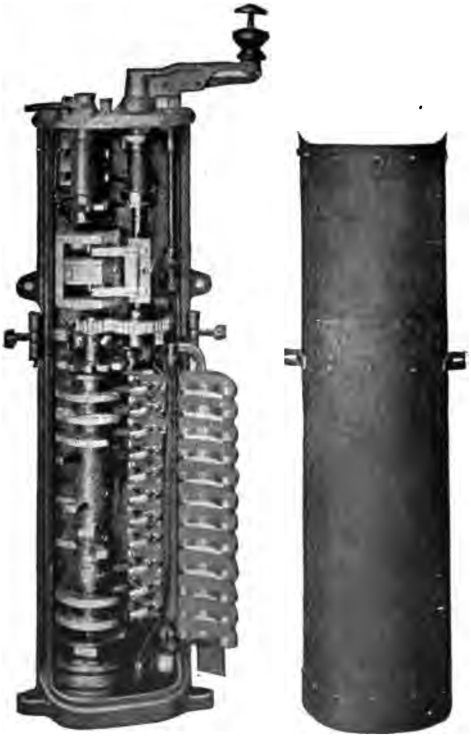


Fig. 82. C-6 Controller.

be held down when the controller handle is in any position except off.

The controller can be supplied with a small pilot valve connecting with the latch operated by the button in the controller handle and operating an emergency valve in the air-brake system. Thus, if the motorman removes his hand from the controller handle, current is immediately cut off from the master controller, and all contactors throughout the train simultaneously drop and the brakes are applied. The emergency valve can be graduated to give any desired application by varying the size of the exhaust port. This valve is shown in Fig. 83.

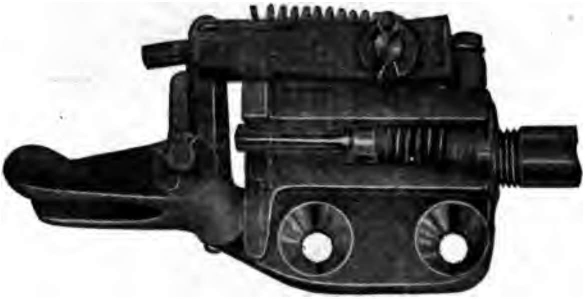


Fig. 83. Emergency Valve.

Another form of master controller used with the Relay Automatic Control is shown in Fig. 84. This controller is provided with a single operating handle connected directly to the cylinder, moving in one direction for forward, and in the other direction for reverse. The cylinder turns against a spring pressure so that if the motorman removes his hand from the handle the cylinder controller is thrown immediately to the off position. This master controller has practically the same cross section

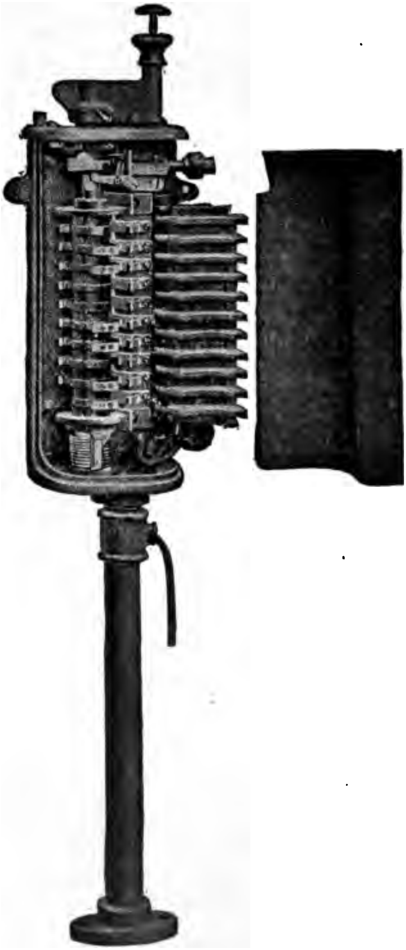


Fig. 84. C-35 Controller.

as the one shown in Fig. 82, but is considerably shorter. For the Non-Automatic equipments for use on city service, a controller of the same size has been provided with a separate reverse handle, and a slow feed device to prevent the controller cylinder from being turned faster than a certain predetermined speed.

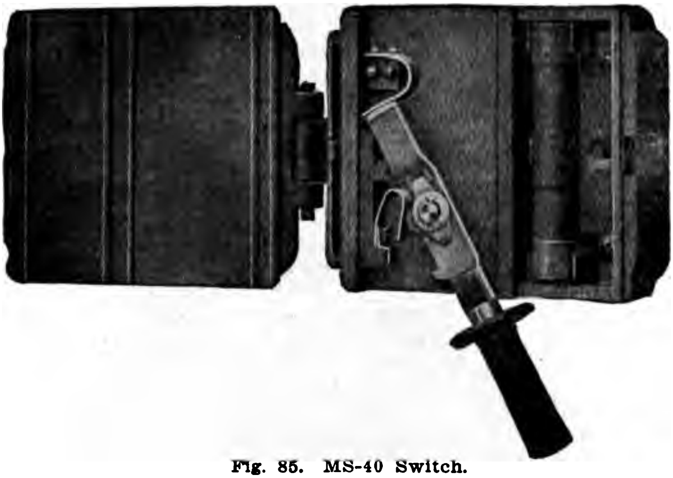


Fig. 85. MS-40 Switch.

MASTER CONTROLLER SWITCH.

Two types of master controller switches are used, depending upon the source of current supply. For equipments operating from a third rail no lightning arresters are used, and the feed for the master controller taps directly from the third rail shoes to an MS-40 switch (Fig. 85) and thence to each master controller. This switch is surrounded by moulded insulation, and is provided with a fuse of the proper capacity, the whole being enclosed and protected by a metal box. One of these switches is used with each master controller, and protects the entire control system when the motorman is operating from that controller.

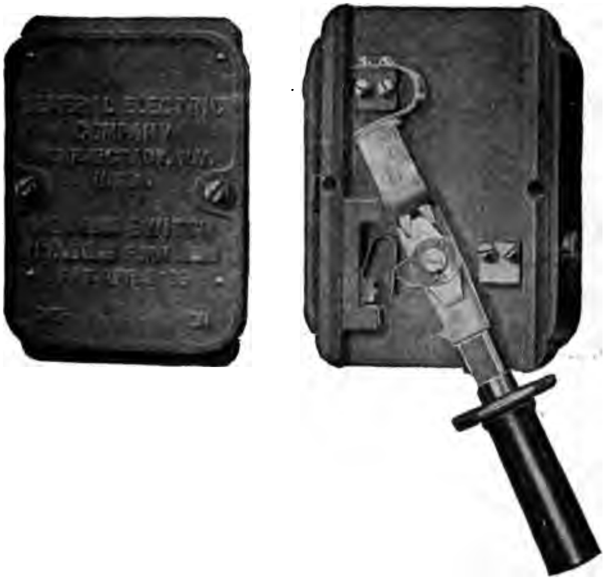


Fig. 86. MS-2 Switch.

For equipments operating on trolley systems one of these MS-40 switches without a blow-out is used as a lightning arrester switch. Current is taken from the trolley through this switch and fuse, then through a small choke, or kicking coil to an MS-2 switch to each master controller. In this case, the MS-2 switch (Fig. 86) serves as a master controller switch. A common fuse protects both the master controller and the lightning arrester switch. Thus, if the lightning arrester becomes damaged, this fuse blows and the car is inoperative until the lightning arrester has been repaired or cut out of service. The master controller switch should be located in the cab within easy reach of the motorman.

CONTROL TRAIN CABLE.

A multiple conductor control cable is used for connecting the control circuits throughout the train. Fig. 78 shows the local connections of this train cable.

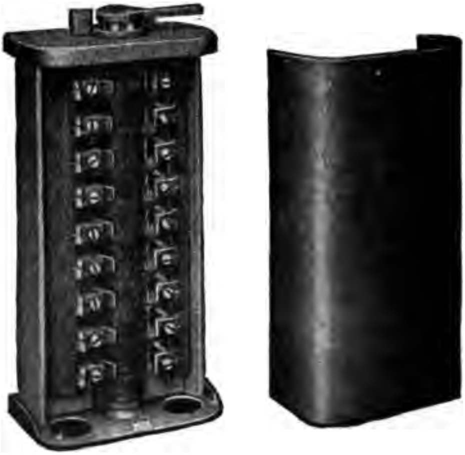


Fig. 87. DH-7 Control Cut-Out Switch.

CONTROL CUT-OUT SWITCH.

A control cut-out switch, consisting of two sets of fingers connected by contacts arranged on an insulating cylinder, is used to connect or disconnect between contactor and reverser coils and cables. This allows the operating coils of the contactors, reverser and circuit breaker on any car to be disconnected from the control circuit without preventing the train being operated from the master controllers on that car. This switch is built up in two forms: the first (Fig. 87) is designed for mounting in the cab or under a car seat, the second is designed for mounting on a switch panel and has no frame of its own, the panel itself serving as a base for the switch.

CONTACTORS.

A contactor (Fig. 88) is an electrically operated switch, consisting of an iron magnet frame with a solenoid coil, and a plunger operating in the coil, connected to a hinged contact arm which makes contact when the switch is closed, with a fixed contact in a moulded insulation arc chute. The arc chute is provided with a powerful magnetic blow-out having its coil in series with the fixed contact. The movable arm is provided with a heavy spring which permits wiping, and rolling action at the moment of contact, and insures proper pressure at the contacts regardless of wear. The contactor is opened by gravity acting in conjunction with the spring pressure.

Contactors are standardized in several different sizes, but they all have the same general characteristics. The levers which constitute the moving arm are of gun metal with hinged pins of tobin bronze to prevent rusting. Contactors are built up in single units, one terminal being fastened directly to the frame, the other to the blow-out coil in the arc chute. A shunt made up of thin strip copper connects between the contact arm and the frame to prevent current passing through the hinges. In handling the contactors, care should be taken not to nick the shunt, nor bend it too sharply, as any injury greatly shortens its life.

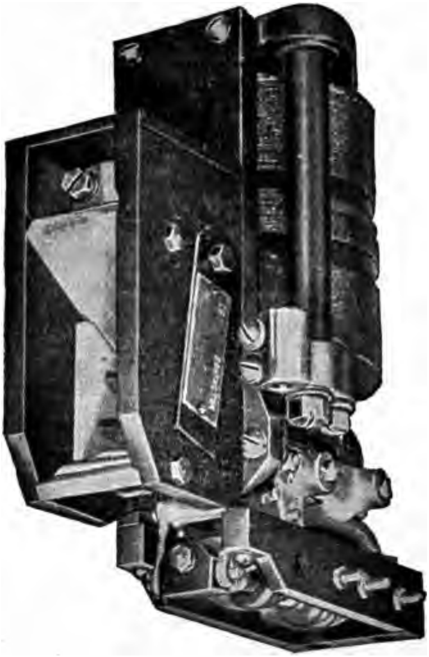


Fig. 88. DB-141 Contactor.

The contactor coil is wound with enameled wire on a brass tube surrounded with mica, with sheet iron flanges. The coil is insulated throughout with horn fibre, oiled muslin and mica, and has a final covering of cord thoroughly painted and waterproofed. To insure a proper insulation, the coils are tested with 5,000 volts A. C. between the winding and shell.

The contactors are assembled and wired complete, with the necessary rheostat tubes in a contactor box before shipment from the factory. These boxes are of two types, viz: one in which the contactors are placed in one row (Fig. 89) and the other in which the contactors are placed in two rows back to back (Fig. 90). The use of the latter type of box is confined almost exclusively to heavy elevated, subway and surface equipments, where inspection is made from a pit. For city and interurban service where it is necessary to inspect the equipments without running the car over a pit the type of box shown in Fig. 89 is recommended, as this can be mounted at the side of the car with the contactors accessible from the outside.

The construction of the two types of boxes is practically the same. The frame which is made up of structural steel and malleable iron castings riveted together, carries the contactors support. For the type of box shown in Fig. 90 a sheet iron support is used, the contactors being fastened with insulated bolts. On the other type of box, the contactors are carried by a wooden support which is protected with fireproof material. The rheostat tubes are mounted in a compartment at the back of the box, and sheet iron covers provided with felt protect the interior of the box from wheel wash, snow and dust. The angle from frame is provided with inlets for conduit, through which outside connections may be made; all internal connections being made at the factory.

The control circuit is wired complete to a connection board at one end of the box. This allows the box of con-

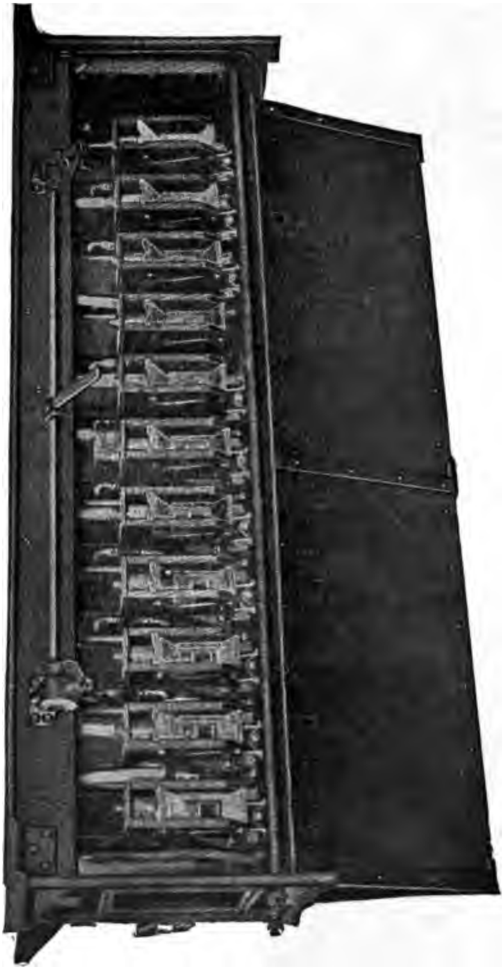


Fig. 89. Contactor Box.

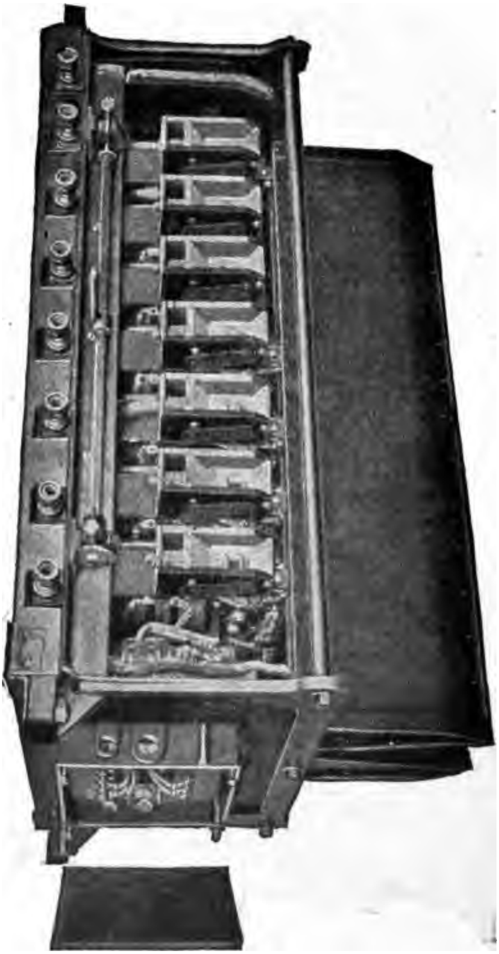


Fig. 90. Contactor Box.

tactors to be mounted on a car as a unit, and the multiple train cable to be run from the cut-out switch, directly to the control connection board at the end of the box. From this connection board, multiple conductor cables also run to the reverser and circuit breaker. All current carrying parts in the contactor box are provided with sufficient insulation to allow the box being grounded.

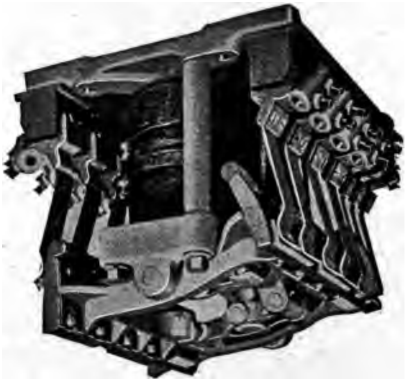


Fig. 91. DB Reverser.

REVERSER.

The reverser (Fig. 91) is a switch, the movable part of which is a rocker arm operated by two electro magnets, one being used for each direction. The solenoid coils of these electro magnets receive their energy from the control circuits and the connections are such that only one can be operated at a time. Wires from the motor armatures, and fields are connected to the fingers of the reverser, and by means of copper plates on the rocker arm, the proper connections of armatures, and fields are established for obtaining a forward or backward motion of the car. The operating coils of the reverser are interchangeable with those of the contactors, although the windings sometimes differ. All insulating parts are of moulded insulation, composed chiefly of asbestos. On four-motor equipments, the reverser is provided with two cut-out switches having handles at the front of the reverser. These handles are marked with arrows indicating the direction of movement, and are also marked to show the numbers of the motors which each switch controls. In operation, the cut-out switch raises the main fingers which supply current to the motors it controls on the positive side, and disconnects the fields of these motors on the negative side from the connection to the contactors. The reverser is mounted in a sheet iron box.

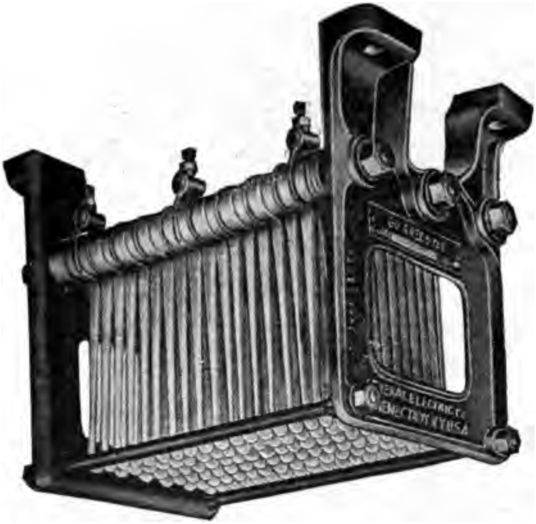


Fig. 92. CG Rheostat.

MOTOR RHEOSTATS.

Motor rheostats (Fig. 92) are made up of cast-iron grids of suitable cross section mounted in a malleable iron frame. These rheostats are insulated throughout with mica, and are built to withstand excessive temperatures without changing the resistance values appreciably, or injuring the insulation. Various sizes of grids are used, depending on the capacity of the motors.

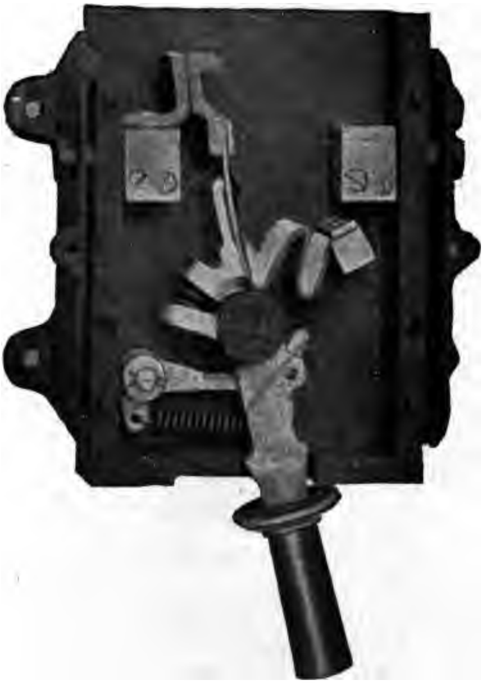


Fig. 93. MS-8 Hood Switch—Cover Removed.

MAIN SWITCH.

A main disconnecting switch is provided for opening the motor circuit. This switch should be located as near as possible to the main tap from the trolley, or third rail. When opened it cuts off current entirely from the main contacts of the apparatus under the car, so that safe inspection can be made, and the control apparatus operated without car movement. For equipments up to and including 200 HP total capacity, an enclosed switch having a quick break with magnetic blow-out is used (Fig. 93) which is located in the cab. For equipments above this capacity, a quick break knife blade switch is used (Fig. 94) which should also be located in the cab, preferably upon a switch panel, if the latter is supplied.

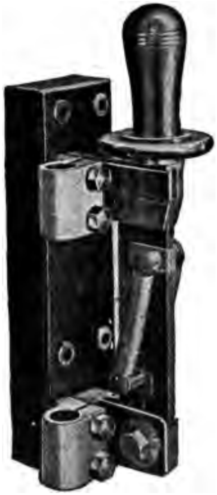


Fig. 94. Main Switch—400 Ampere Capacity.

CIRCUIT BREAKERS.

An electrically operated circuit breaker is now provided with each standard equipment. This is enclosed in a suitable iron box designed for mounting underneath the car. The circuit breaker is similar in general design to the contactor but is provided with a brush contact, and suitable auxiliary contacts to prevent arcing at the brush. There are two operating coils—one for closing the breaker and the other for tripping it. The circuit breaker is held closed by a latch, which is opened when the tripping coil is energized. Two separate train wires

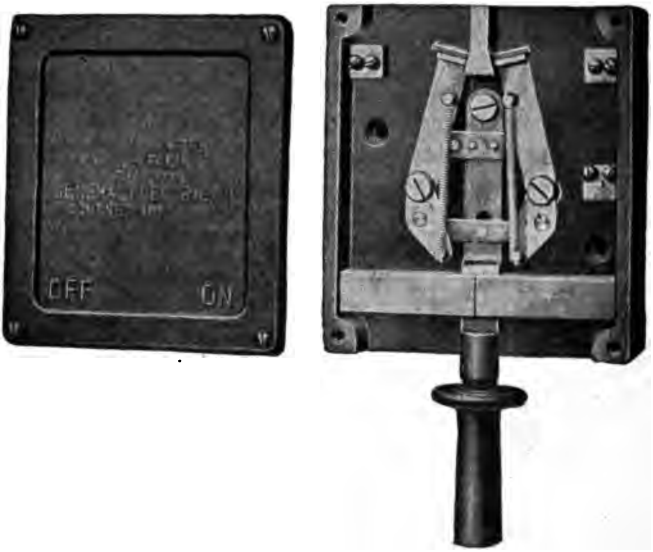


Fig. 95. Circuit Breaker Setting and Tripping Switch.

are used for operating the circuit breaker and a single pole, double throw, enclosed switch is installed in each cab for handling the setting and tripping circuits. This switch is provided with a spring for returning it to the off position as soon as the handle is released. The switch is shown in Fig. 95.

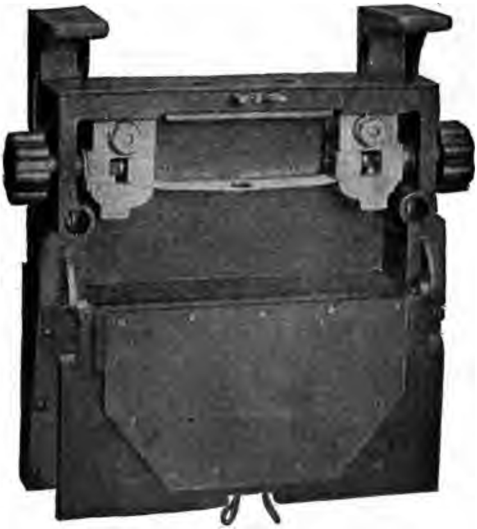


Fig. 96. MA-13 Fuse Box.

MAIN FUSES.

A main fuse is supplied (Fig. 96) for protecting the equipment from short circuit in case the circuit breaker should fail to act. The fuse consists of copper ribbon held in a fuse box provided with a magnetic blow-out. The section of copper is decreased at the center by a hole punched in the fuse to locate the burning. The fuse is readily replaced, and as the main switch is located between it and trolley, the motorman can handle the fuse without danger of injury from shock if the switch is opened.

The apparatus already described is common to all types of equipments. For Automatic Master Control and Relay Automatic Control, however, relays are required in addition.

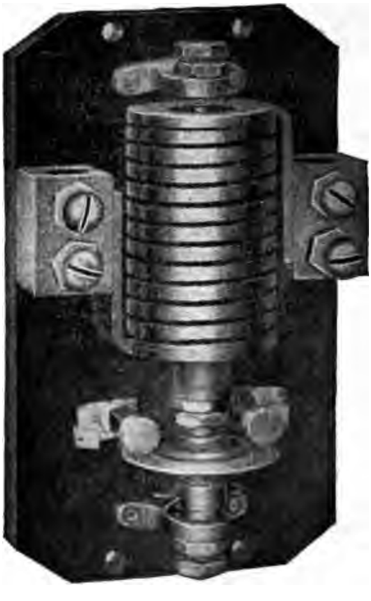


Fig. 97. Current Relay.

CURRENT RELAY.

The current relay used with the Automatic Master Control is shown in Fig. 97. This consists of a series coil operating a plunger which carries a disc contact. The relay is mounted on a moulded insulation base, and has platinum points making contact with silver discs, the design being such as to insure clean contacts at all times.

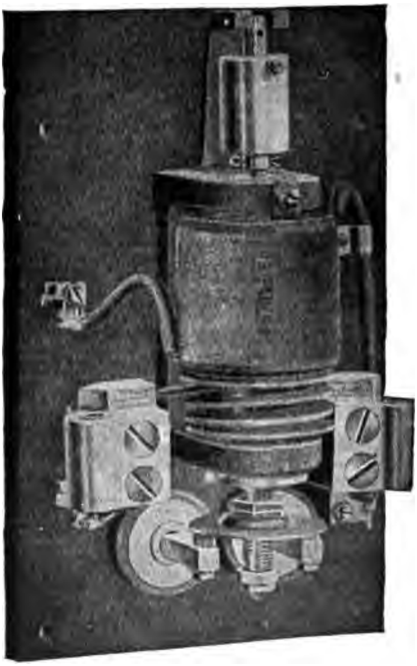


Fig. 98. Current Relay.

The current relay used with the Relay Automatic Control is shown in Fig. 98. This relay has two coils, shunt and series, and is so designed that it is picked up by the shunt coil and is held closed by the series. The circuit for the shunt coil passes through the contacts, so that each time the plunger lifts it opens its own picking up circuit.

The contacts are provided with coils which both furnish a magnetic blow-out, and give a snap action effect. The disc and contact pieces are of iron, the contacts themselves being silver on silver. The use of the snap action is to keep the disc in contact with the studs until the relay plunger has nearly closed, when a shoulder on the plunger strikes the disc and breaks the contact, the spring under the disc immediately raising it to the proper clearance. A dash-pot is provided with its piston connected to the plunger to prevent rebounding.

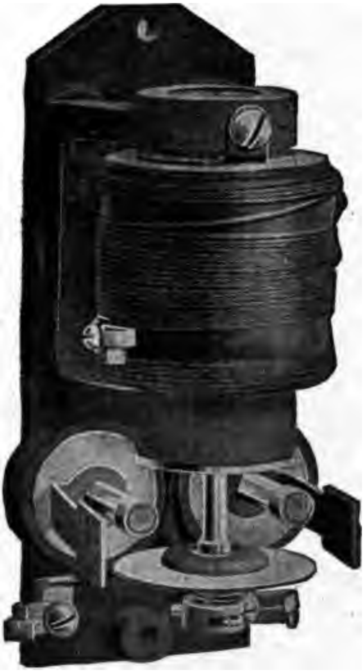


Fig. 99. Potential Relay.

Both of the above relays should preferably be mounted on a switch panel, and care must be taken to keep them free from dust.

POTENTIAL RELAY.

The potential relay used with the Relay Automatic Control shown in Fig. 99 consists of a finely wound coil having a plunger with a single disc provided with a magnetic blow-out. The coil on this relay is connected directly between the frame of one of the line contactors and ground, suitable rheostat tubes being inserted to prevent overheating.

SWITCH PANEL.

On large systems where considerable care is given to the details of equipment, it has become standard practice to install a switch panel in the motorman's cab. The panel is made of slate, with an angle iron frame for mounting in a compartment provided by the car builder. These panels are not included in a standard equipment and are generally special to meet the specific conditions of an equipment. Figs. 100 and 101 show typical panels.

The panels form an ideal arrangement for centralizing all the auxiliary devices, including lighting and heating switches and fuses, air compressor switch and fuse, lightning arrester switch and fuse, main switch, current relay and control cut-out switch. If the function of the different switches and sizes of fuses are plainly marked on the panel, the car crew always know just where to go to open or close any auxiliary switch or replace a fuse.

The panel compartment should be supplied with a lock.

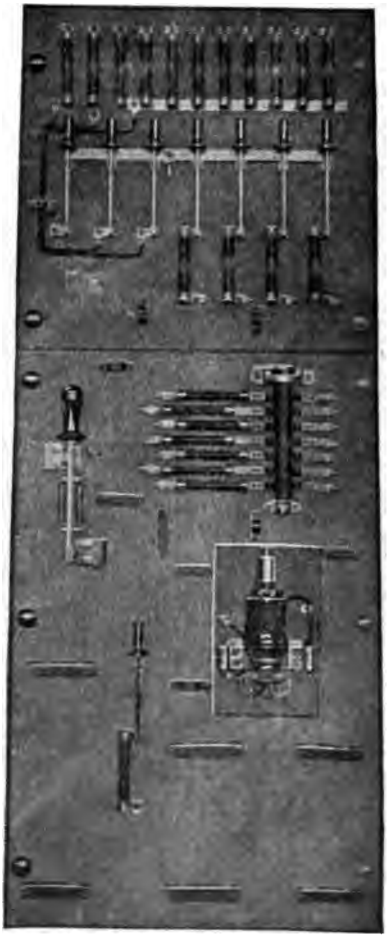


Fig. 100. Switch Panel.

It should be lined completely with non-inflammable material, and provided with a sheet iron door to reduce fire risk to a minimum.

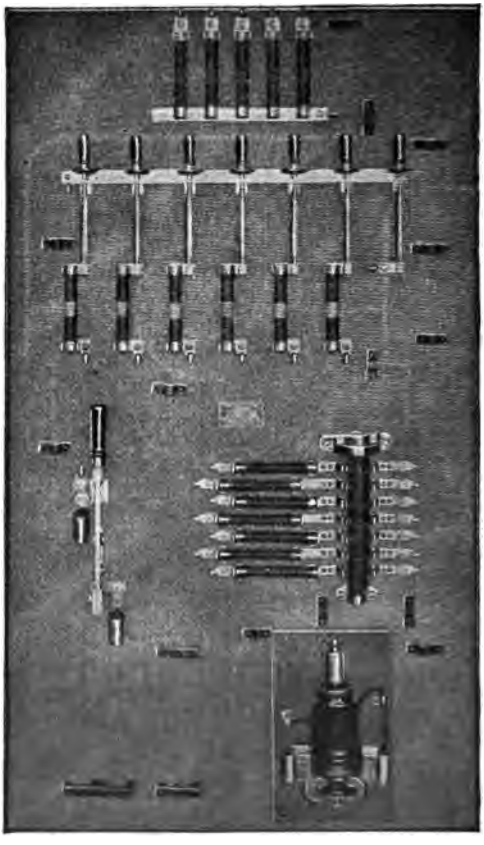


Fig. 101. Switch Panel.

This method of centralization simplifies repairs by standardizing all the small auxiliary switches, and at the same time cuts down the number of spare parts that have to be carried for this purpose.

BUS LINE.

On third rail equipments a bus line is sometimes installed to supply continuous current throughout the train in crossing gaps which are too long to be bridged by the shoes of a single car. The bus line also insures against failure of current due to sleet on the rail, as it enables the supply to be taken from the shoes on the rear cars.

The bus line is not included in a standard equipment. It consists of a set of bus line coupler sockets with bus line jumper, two bus line connection boxes and two bus line fuses for each motor car together with the necessary cable for making connections. The coupler sockets, jumper, and connection box are generally similar to those used for the control train cable except that they are designed with a single stud of larger capacity. The bus line fuses are the same as the main fuse used with the car equipment.

INSTALLATION.

From the operating point of view the object of a car equipment is to insure continuous operation with the minimum cost of maintenance and repair, and this object should be borne in mind from the beginning of the installation. Apparatus, which either due to its construction or functions, requires frequent inspection, should be located in the most accessible places, and in all cases, care must be exercised to provide sufficient clearance round it for ready inspection. Location is also largely influenced by ability of the apparatus to withstand wheel wash, brake shoe dust, etc.

The parts of the equipment designed for location under the car, are provided with dust proof sheet iron covers while other parts, such as relays, control cut-out switches, etc., must be placed in the cab—preferably on a slate panel in a dustproof compartment.

The layout of an equipment is, therefore, a very important part of the installation, and should always be supervised by some one who understands the functions of the apparatus.

As a rule on interurban equipments it is best to keep all electrical apparatus on one side of the car, reserving the other side for air brake equipment. This can be done by placing the contactor box between the needle beams, and as near the side of the car as possible, thus allowing room for the motor rheostats in a row between the back of the box and the center line of the car. The reverser should be located at one end of the contactor box, and the circuit breaker at the other. When facing the side of the car on which the contactor box is mounted the reverser should be at the right hand end, and should be adjacent to the motor truck on a two-motor equipment. This is based on the assumption that inspection will be made from that outside, which is the usual practice on interurban and suburban equipments.

In mounting the contactor, reverser and circuit breaker boxes, it must be remembered that the covers when open must have clearance on all parts of the road bed, since quite apart from the fact that a broken catch may allow the cover to drop, there is always the possibility of a car going into service with its box covers down due to carelessness on the part of the car barn men. The circuit breaker must be insulated from ground either by insulated bolts or by mounting on hardwood supports. The contactor and reverser boxes may be grounded and should be supported on wrought iron hangers or bolted to the car frame. Dimensions of hangers vary according to the space, but for the contactor box they should never be less than ½"x4" and for the reverser box ½"x3". All nuts should be provided with lock washers and it is good practice to drill the bolts for cotter keys.

The main fuse box should be at the side of the car near the circuit breaker, with the kicking coil and lightning arrester directly behind. This reduces the amount of power wiring to a minimum.

With the above arrangement the main cable runs from trolley to the main switch in the cab, preferably using asbestos covered cable in hardwood moulding. From this switch it should be run in conduit to the main fuse, kicking coil and circuit breaker into the contactor box.

Leads from the contactor box to the rheostats may in many cases use the nipples shipped with the bell mouths on the box but a better practice is to substitute a piece of conduit long enough to reach over to the rheostat. The conduit can then be rigidily fastened to the rheostat support, preferably by means of hook bolts.

Leads from the contactor box to the reverser and relay, when the latter is used, and the motor leads for 125 H. P. motors or larger should be run in individual conduits on account of the size of the cable. This is easily done as the reverser is located close to the motor truck on a two-motor equipment, and on a four-motor equipment of this capacity a separate reverser is used for each pair of motors. On equipments having motors of less than 125 H. P. each the leads to each motor should run in a common conduit.

Fig. 102 shows the method of making the motor lead connections and has been used on the larger type of motors with very satisfactory results. It consists of a set of hardwood cleats, and individual clamp or clasp connectors which are soldered to the ends of the leads. One cleat permanently clamps the leads from the reverser; the other is removable and clamps the leads from the motors.

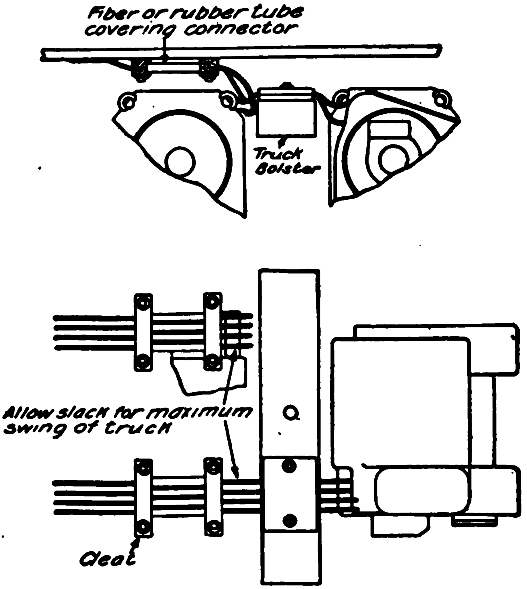

Fiber or rubber tube covering connector
Truck Bolster
Allow slack for maximum swing of truck
Cleat

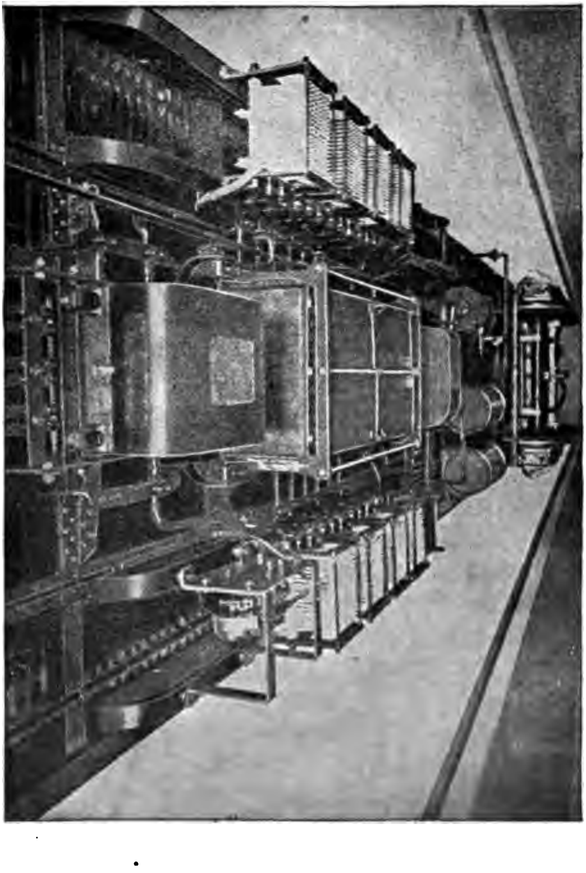
Fig. 102. Method of Installing Motor Leads.

The connection is made between the cleats which are counter-bored to receive the ends of fibre tubes which serve as insulation for the connectors. The leads from the outside motor are brought back on the truck and preferably arranged so that the leads from both motors go up to the car floor at the same point, and use common cleats instead of being spaced as shown. On equipments using motors of 60 H. P. or less, motor lead connection boxes are recommended. These boxes are built of cast iron, tapped for conduit from the reverser and are provided with switch clips which receive blade terminals soldered to the motor leads.

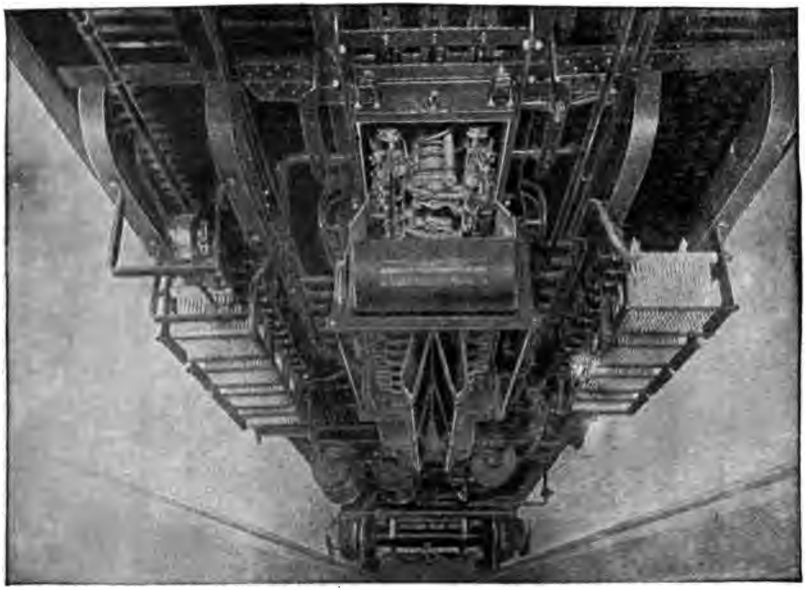
The train line cable should be run in conduit from the coupler sockets, master controllers and cut-out switch to the connection boxes, and from the cut-out switch to the contactor box. Coupler sockets, connection boxes, and the contactor box frame are tapped to receive the conduit, but bell mouths must be used at the controllers and cut-out switch. Diagrams are supplied with the equipment showing the cable preparation, and connections for the above apparatus, and all terminals have copper clips which should be clamped and soldered to the individual conductors. Three conduit entrances are provided at the control connection board in the contactor box tapped for 1″ conduit, but they are supplied with reducing nipples so that 4″ conduit can be used. One entrance is for the cable to the cut-out switch. The other two should be used for the cables running to the reverser and circuit breaker. These cables should be made up of individual 19 No. 25 conductors and run in ¾″ conduit.

The above description only relates to the connections and support of apparatus under the car floor, such apparatus being of primary importance as it has to handle the motor current.

In the motorman's cab the arrangement of apparatus depends upon the available space, and existing standards on the road. All master controllers are designed to occupy the least possible space from back to front, and may be fastened directly against the partition or the front wall of the cab. The master controller switch in all



Bottom of Interborough Rapid Transit Car Showing Location of Apparatus Arranged for Pit Inspection with Boxes Closed.



Bottom of Interborough Rapid Transit Car Showing Location of Apparatus Arranged for Pit Inspection with Boxes Open.

cases, and the enclosed main switch on small equipments should be within easy reach of the motorman, but the remainder of the auxiliary apparatus, such as control cut-out switch, lightning arrester switch, control fuses and relays may be located to suit the individual conditions. The best practice is to install a switch panel in a small compartment opening into one of the cabs on which the above apparatus as well as the switches and fuses for lights, heaters, and air compressor may be mounted. This centralizes all of the auxiliary apparatus and by marking the different switches and fuses, a great deal of confusion is avoided.

The wiring in the cab and car body varies with the type of construction. On steel cars all of the auxiliary wiring should be laid in conduit, while on wooden cars, asbestos covered cable in hardwood moulding meets the underwriters' requirements and is the most satisfactory method of installation.

Unlined conduit of the Loricated type is recommended for use, except for heater and lighting circuits where a flexible metallic conduit should be used. All apparatus is tapped to receive the Loricated conduit which runs in the sizes shown in the following:

TABLE OF CONDUIT SIZES.

Nominal Inside Diameter.	Actual Inside Diameter.	Actual Outside Diameter.	Weight per Lineal Foot.
⅜ in.	.493 in.	.675 in.	.56 lbs.
½ "	.622 "	.840 "	.84 "
¾ "	.824 "	1.050 "	1.12 "
1 "	1.048 "	1.315 "	1.67 "
1¼ "	1.380 "	1.660 "	2.24 "
1½ "	1.610 "	1.900 "	2.68 "
2 "	2.067 "	2.375 "	3.61 "

NOTE: Loricated Conduit is usually supplied in 10 Foot lengths with standard pipe couplings.

The best practice is to depend entirely upon the insulation of the cables and regard the enamel lining of the conduit merely as a protection from rust.

SIZES OF CABLES FOR EQUIPMENTS.

HP per Motor.	Trolley. Four-Motor	Trolley Two-Motor.	Single Motor Lead.	Rheostat Lead Four-Motor.	Rheostat Lead Two-Motor.
25	2 B. & S.	4 B. & S.	6 B. & S.	6 B. & S.	6 B. & S.
40	0 B. & S.	4 B. & S.	6 B. & S.	6 B. & S.	6 B. & S.
50	00 B. & S.	2 B. & S.	6 B. & S.	4 B. & S.	6 B. & S.
60	000 B. & S.	2 B. & S.	4 B. & S.	4 B. & S.	6 B. & S.
65	000 B. & S.	1 B. & S.	4 B. & S.	4 B. & S.	6 B. & S.
75	0000 B. & S.	0 B. & S.	4 B. & S.	2 B. & S.	4 B. & S.
100	250,000 C. M.	00 B. & S.	2 B. & S.	2 B. & S.	4 B. & S.
125	350,000 C. M.	00 B. & S.	1 B. & S.	1 B. & S.	4 B. & S.
150	500,000 C. M.	0000 B. & S.	0 B. & S.	—	2 B. & S.
175	—	0000 B. & S.	00 B. & S.	—	1 B. & S.
200	—	250,000 C. M.	00 B. & S.	—	1 B. & S.

Seven wire train and jumper cable is used on relay automatic control.
Ten wire train and jumper cable is used on automatic master and hand control.
19 No. 25 cable is used on all auxiliary control circuits.
On four motor equipments where two motors are permanently in parallel, use the same size cable as trolley for two motors.

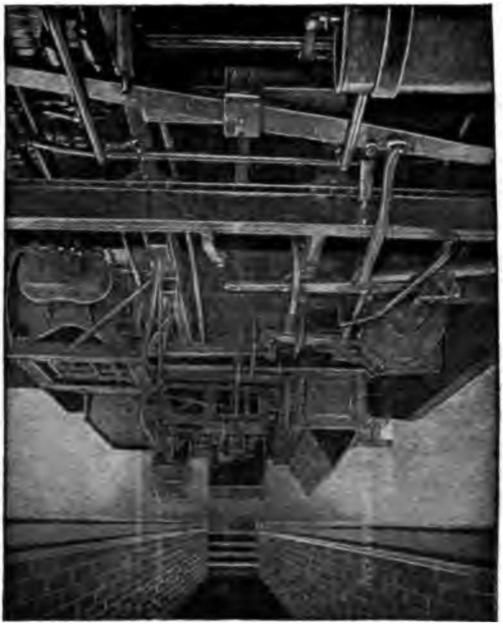
TABLE OF CABLES.

	SINGLE CONDUCTOR FOR USE IN CONDUIT					FLAME PROOF CAR WIRING CABLES.				
	No. Strands	Bare Diam.	Thickness Rubber	Finished Diam.	Wgt. per ft. lbs.	No. Strands	Bare Diam.	Thickness Rubber	Finished Diam.	Wgt. per ft. lbs.
250000 CM	37	.576 in.	$\frac{3}{32}$ in.	.875 in.	1.032	37	.576 in.	$\frac{3}{32}$ in.	.98 in.	1.138
No. 0000	19	.528 "	$\frac{5}{64}$ "	.790 "	.835	19	.528 "	$\frac{5}{64}$ "	.90 "	.937
No. 000	19	.470 "	$\frac{5}{64}$ "	.732 "	.683	19	.470 "	$\frac{5}{64}$ "	.84 "	778
No. 00	19	.419 "	$\frac{5}{64}$ "	.681 "	.563	19	.419 "	$\frac{5}{64}$ "	.79 "	.650
No. 0	19	.375 "	$\frac{5}{64}$ "	.637 "	.464	19	.375 "	$\frac{5}{64}$ "	.74 "	.545
No. 1	19	.332 "	$\frac{5}{64}$ "	.594 "	.381	19	.382 "	$\frac{5}{64}$ "	.69 "	.461
No. 2	7	.293 "	$\frac{1}{16}$ "	.523 "	.289	7	.293 "	$\frac{1}{16}$ "	.60 "	.353
No. 4	7	.232 "	$\frac{1}{16}$ "	.462 "	.197	7	.232 "	$\frac{1}{16}$ "	.54 "	.255
No. 6	7	.184 "	$\frac{1}{16}$ "	.404 "	.139	7	.184 "	$\frac{1}{16}$ "	.49 "	.189
No. 12	7	.092 "	$\frac{3}{64}$ "	.280 "	.027	7	.092 "	$\frac{3}{64}$ "	.32 "	.030
19/No. 25	19	.090 "	$\frac{3}{64}$ "	.278 "	.05	19	.090 "	$\frac{3}{64}$ "	.31 "	.055
No. 14	7	.073 "	$\frac{3}{64}$ "	.261 "	.020	7	.073 "	$\frac{3}{64}$ "	.30 "	.023

NOTE:

The standard, single conductor, car wiring cables for use in conduit are stranded from tinned copper wire and have a separator between conductors and rubber insulation and are finished with a tape and weather proof braid of 10's/2-ply cotton.

The standard flame proof wiring cables are stranded from tinned copper wire and have a separator between the rubber and conductor, and are covered with one compounded cotton braid and one asbestos paint filled braid.



Bottom of Philadelphia Rapid Transit Car Showing Air Brake and Control Apparatus Located at Opposite Ends.

QUESTIONS AND ANSWERS.

DETECTION OF CAUSES FOR FAILURES OF CAR OR TRAIN MOVEMENT.

The following questions and answers have been prepared to help motormen in case of failures of car or train movement that may ordinarily occur in operating Type M Control. Though all the possible troubles are not covered and some of the conditions referred to below may not actually arise, yet the questions and answers should give motormen a good insight into the operation of the control circuits and enable them to more quickly supplement their knowledge of the working of their particular control system than would otherwise be the case. After motormen have familiarized themselves more fully with operating conditions, they may frequently be able to exercise their own judgment to better advantage.

Q. 1. If a car or train fails to move after the master controller has been turned on, what should be done?

A. The lighting circuit switches should be switched on to ascertain if there is power on the trolley or rail.

Q. 2. If there is current on the car what should be done?

A. The master controller should be moved to the first point, then the overhead master controller switch opened to see if the circuits are closed, which will be indicated by a slight arcing at the switch.

Q. 3. What would cause the failure of the master control or train cable circuits, indicated by the absence of arcing?

A. 1st. An imperfect master control fuse. 2d. Imperfect contact in the master controller. 3d. Imperfect 4-amp. fuses in the control circuits.

Q. 4. What should be done to detect an imperfect master controller fuse?

A. Open the control circuit switch, examine the fuse and renew it if blown. If the fuse is not blown the trouble is evidently elsewhere.

Q. 5. How can an enclosed fuse that has been blown be detected?

A. A small circle in the center of the label will be charred and blackened if the fuse is blown. This is called the "telltale" of the fuse.

Q. 6. If a master controller fuse blows again after renewing, what should be done?

A. Operate from the other master controller.

Q. 7. What should be done to detect imperfect contacts in the master controller?

A. Open the master controller switch; then remove the controller cover and note the movement of the contact fingers. Turn the handle around slowly and see that each finger makes good contact with its cylinder contact segment. If any contact is imperfect, endeavor to readjust; failing in this, it will be necessary to operate another controller—either on that or another car, if there is a train of cars.

Q. 8. What should be done to detect imperfect fuses in the circuits of the control apparatus?

A. Examine the 4 amp. fuses, which are ordinarily located in a group, near the cut-out switch. If the "telltales" of any of these fuses show that they are blown, renew the defective fuses.

Q. 9. If the master controller switch breaks current on the test (see answer to Q. 2) what does it indicate?

A. Either (1) that the control is operating properly and that the main fuse is blown or (2) that some one of the control 4-amp. fuses is blown so that some of the contactors are operating but that others necessary to close the motor circuit are not, or (3) that some one finger in the master controller is not making good contact.

Q. 10. What should be done?

A. (1) Open the main switch and pull down the trolley as an extra precaution, then examine the main fuse and renew if blown. (2) If the main fuse is not blown examine the 4-amp. control fuses, and renew if any one is blown as shown by the telltale. (3) If no fuse is blown, open the overhead master controller switch, remove the cover from the master controller, and see that all fingers make good contact with the cylinder segments, when turning the handle around. Adjust if possible any finger which is not making good contact.

Q. 11. If shortly afterwards the main fuse blows again on a four-motor equipment, it indicates motor trouble. What should be done?

A. Endeavor to locate the motor on which there is trouble. If it is on No. 1 or No. 2 motor, throw the handle of the left hand motor cut-out switch on the reverser; throw the right hand switch for No. 3 or No. 4 motors. If the trouble cannot be located readily, try cutting out one pair of motors. If the trouble is not relieved cut this pair in again and cut out the other pair.

With automatic relay control, when accelerating with one pair of motors cut out, the controller handle must not be moved and held in a running position either on "series" or "parallel" in the ordinary manner. After moving the handle up it must be quickly brought back to lap—series lap for series—and multiple lap for multiple. This must be repeated until the car is up to speed, when the handle can be held in the running position. This is called "notching" the controller up. The automatic feature is rendered partially inoperative when one pair of motors is cut out, hence the control should be notched up.

Q. 12. If cars are being operated in a train what are the causes, which would render a train entirely inoperative?

A. Imperfect master controller fuse, or imperfect contact in master controller, or a loose coupler jumper between the head car and the next.

Q. 13. What should first be done in case a train fails to move?

A. Make the same tests on the master controller fuse and master controller as for single car operation and then examine the coupler jumpers to see that they are properly in place.

Q. 14. If the master controller fuse blows again after being renewed, what should be done?

A. 1st. Try the master controller on another car. 2d. If the fuse blows here also, open the main switches, pull out the jumpers between the cars, and then try each car separately, with its master controller. Leave the jumpers out of that car which blows a fuse and operate from the other car if there is a two car train or from that car which will give the greatest number of motor cars coupled together, if there are three or more cars.

Q. 15. What causes would tend to reduce the speed of a train?

A. 1st. One or more cars being dead or inoperative from any of the causes above referred to, such as a main fuse blown, or some of the 4-amp. fuses of the control circuit being blown on individual cars. 2d. Coupler jumpers not being in place between cars or not making proper contact. 3d. Imperfectly acting air valves preventing the brakes releasing properly.

Q. 16. What should be done?

A. 1st. Examine all coupler jumpers to insure that they are all in place and make good contact. 2d. If the jumpers are properly in, examine the brakes and release any which may be sticking, following air-brake instructions. 3d. If there is no evidence of either of the above troubles and the train is running too slowly to make time, endeavor to locate the car which is inoperative, first examining all the main fuses to see if any are blown. Renew any fuse or fuses which may be blown after first opening the main switches. 4th. If the main fuses are intact, examine the 4-amp. control circuit fuses on the different cars and renew any which may be blown.

ROTARY CONVERTERS.

As the sub-station is the link between the transmission line and the trolley wire, so in like manner the rotary converter is a connecting link between alternating and direct current systems—it combines in a single machine the functions performed by the two machines described above. Thus in one sense it may be regarded as an alternating-current synchronous motor, driving a direct-current generator, or if the machine be inverted, it may be considered a direct-current motor driving an alternating current generator.

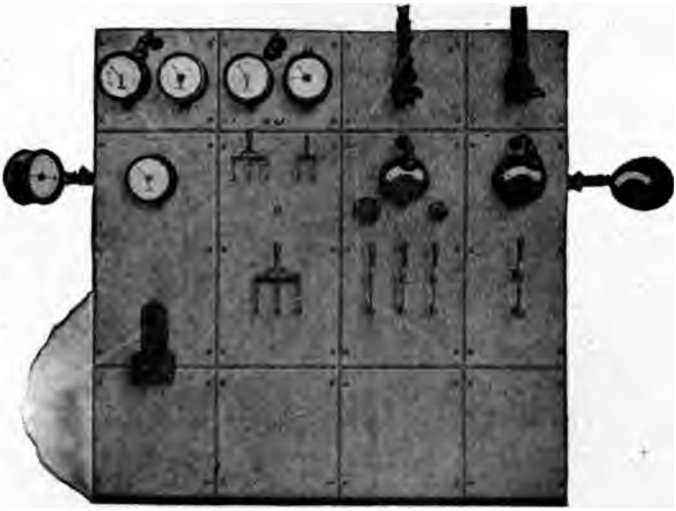


Fig. 103. Typical Rotary Converter Switchboard.

As direct current cannot readily be generated at or transformed to a high voltage, which economical distribution dictates, alternating current is almost invariably used for all except very small electrical power transmissions. Wherever direct current is used, as in direct current railway lines, the alternating current must be transformed into direct current. While, of course, this can be accomplished by means of a motor-generator set, consisting of an alternating current motor connected to a direct current generator, the higher efficiency and lower cost of the rotary converter accounts for the almost universal practice of using it in preference to the motor-generator on low frequencies.

Rotary converters have many of the features which distinguish the most modern direct-current machines; the only material difference being the addition of collector rings connected to certain points of the armature winding. The number of such connections depend on the number of poles and phases.

The machine is built for single-phase, two-phase, three-phase or six-phase circuits, although single-phase and six-phase converters are seldom desired. A two-phase converter is provided with four collecting rings and a three-phase converter is provided with three collecting rings. As it is usually found expedient to transmit the alternating current at high pressure, transformers must be employed for lowering the potential to secure the proper direct voltage. Where the converter is operated from direct to alternating current, transformers are usually employed to raise the voltage for transmission.

A rotary converter may be separately excited, but it is usually shunt wound or compound wound, depending upon the nature of the service. When the load is variable, as in railway service, the machine is compound wound, which tends to maintain the direct current voltage constant, by compensating for the drop in the supply circuit as the load comes on. The ratio between the alternating and direct current voltages of a rotary converter depends upon the number of phases, upon the wave form of its alternating current, upon the lead given to the direct current brushes and to a slight extent upon the field excitation. In any given converter, therefore, the direct current voltage depends practically upon the voltage of the alternating current applied. To a smaller extent it depends upon the armature drop, which diminishes the voltage ratio in slight proportion with the load when running a. c. to d. c. and increases the ratio when running

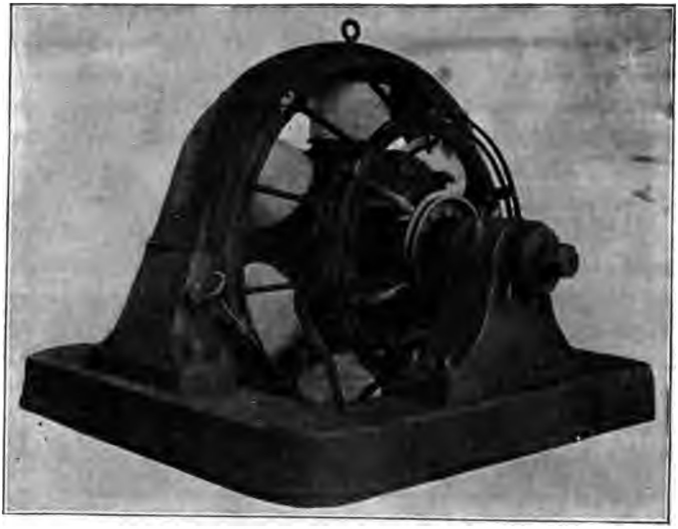


Fig. 104. Allis-Chalmers 25 Cycle Rotary Converter (Commutator End).

d. c. to a. c. This will be seen readily by referring to a saturation curve. With a sine wave the ratios of conversion are approximately as follows:

Single Phase	Two Phase	Three Phase	Six Phase
.71	.71	.61	.71 or .61

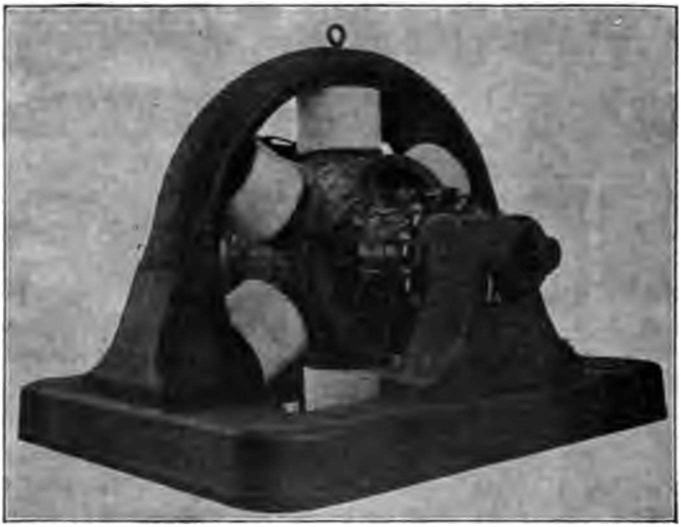


Fig. 105. Allis-Chalmers 25 Cycle Rotary Converter (Collector End).

Thus, if the direct current voltage be 550 volts, the alternating current, if two phase, will be .71 x 550 or 390 volts, and if three phase, it will be .61 x 550 or 335 volts. The ratio of conversion in the six-phase converter is .71 with the star connection or .61 with the double-delta connection. The variation from these figures with wave forms in commercial use are taken into account in the ratios of the transformers used in connection with the rotary converters.

The rotary converter built by the Westinghouse Company presents in its frame the same mechanical features as are found in its well-known line of direct current machines. In the smaller sizes the frame, bed plate and bearing supports are cast in one piece, thus giving a rigid construction which permits of handling the machine as a unit. In machines of large size these parts are usually separate castings in order to limit the weight of the pieces to be handled. This construction also allows of the adjustment of the component parts of the machine to maintain the central position of the armature.

The machine is of the multipolar type, having laminated steel poles cast or bolted to its iron yoke and carrying easily removable field coils. If the windings are compound, the series and shunt coils are insulated separately. The armature is of the slotted drum type with either a two-circuit or multiple type of winding. The coils are machine wound and they are of such a shape as to give a thoroughly ventilated winding.

The number of poles in a rotary converter is dependent on the speed of the armature and the frequency, as is the case with all alternating current machinery. This particular feature accounts for the difficulty in designing rotary converters for high frequencies, for the maximum armature speed is limited by the maximum safe speed of the periphery of armature and commutator. With a given speed, however, the number of poles is proportional to the frequency, and, with a given maximum speed of armature and commutator periphery, the distance between adjacent poles and, therefore, adjacent brush holders, is inversely proportional to the frequency. With high voltage 60 cycle converters these facts necessitate high commutator speeds, short distances between poles and between brush holders, narrow commutator segments and a high voltage between adjacent segments, resulting in a tendency to flashing over between brushes at sudden overload. This should always be borne in mind when choosing the frequency of a system on which rotary converters are to be used, and it applies particularly to 500 and 600 volt railway rotary converters, which are required to withstand much more severe service than is ever experienced on lighting systems.

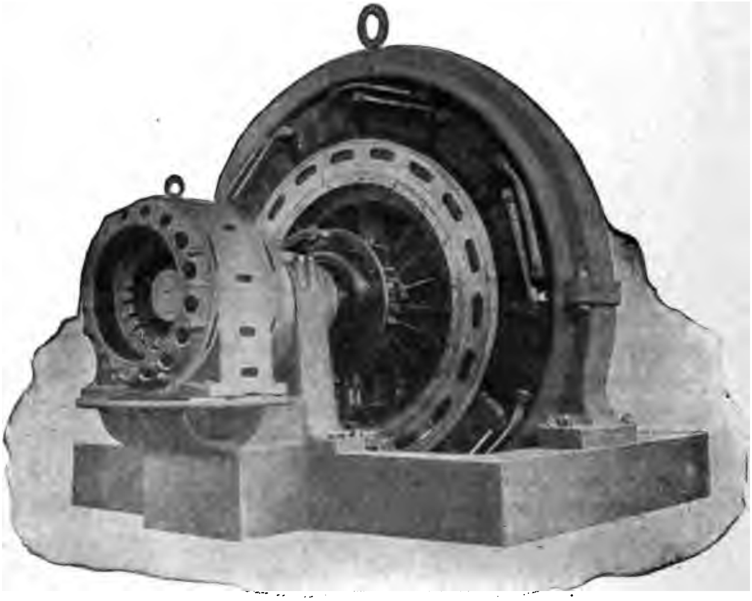


Fig. 106. Westinghouse 1,500 K. W. Rotary Converter, **Pennsylvania**, New York and Long Island R. R.

In the erection of a rotary converter the following considerations should as far as possible be observed:

First. It should not be located in a position where it would be liable to exposure to moisture, as from dripping pipes, or escaping steam.

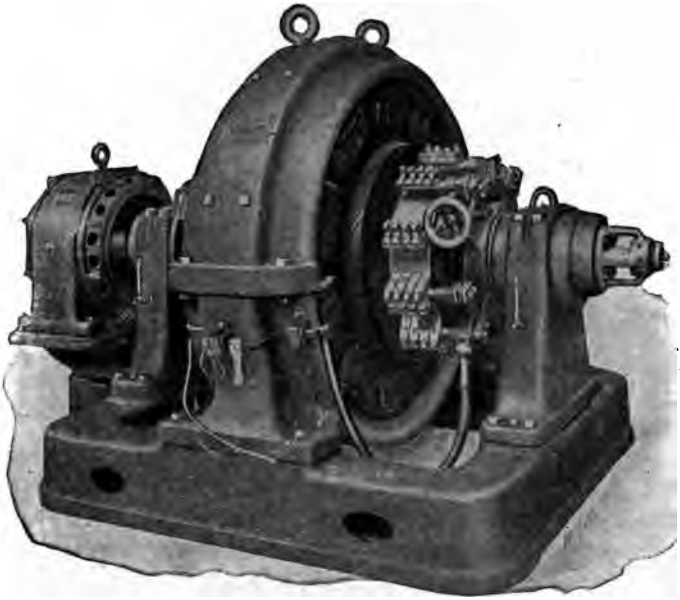


Fig. 107. Westinghouse 300 K. W. Rotary Converter, 600 D. C. Volts, 500 D. C. Amperes, Three-Phase, 60 Cycles.

Second. It should not be exposed to dirt or dust, especially from coal.

Third. It should be located in as cool and well ventilated a place as possible. The temperature of the machine depends upon the temperature of the air surrounding it.

Fourth. It should be so located as to allow easy access to the alternating current brushes, and also to the commutator. These are the parts requiring special attention. Rotary converters should be set on substantial foundations in order to prevent vibration when running.

The following list of instructions refer more particularly to Westinghouse machines but much of it will apply to others.

Insulation of Frame. Whether the frame should be insulated from the ground is a matter to be determined by the engineer in charge of the plant, but rotary converters are usually not insulated. However, the following remarks which apply to alternating current practice may not be amiss: .

Generally speaking, the strain on the insulation of the windings will be decreased and the danger to the attendant increased by insulating the frame. When, however, it is considered advisable to insulate the frame, the foundation should be capped with a stout wooden frame bolted down. The bolts which hold this frame to the masonry should not come in contact with those which hold the machine to the frame nor should any metal or electrical conductor join the two sets of bolts. The wooden insulating frame under the machine may also be covered with some insulating waterproof paint or compound.

Erection of machine. When placing the parts of a machine in position the following points should be observed:

(1) Set the lower half of the field in position and place the armature in its bearings, having first carefully examined the bearings and oil wells to be sure that they are clean and free from dirt. Be sure that the oil rings are in place and in good running order,

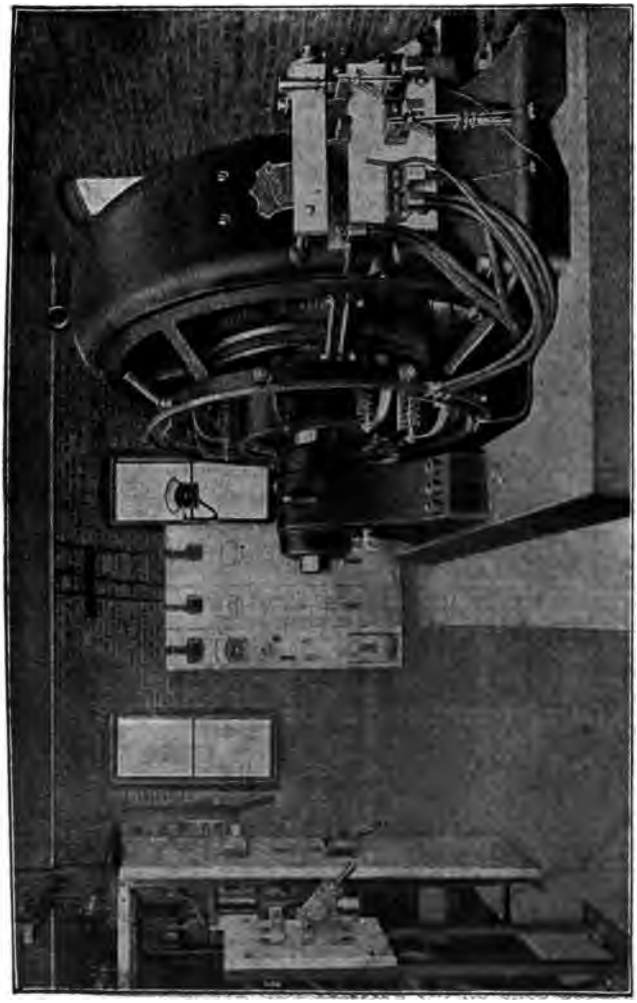


Fig. 108. 400 K. W. 375 R. P. M. Allis-Chalmers Rotary Converter, Installed in the Sub-Station of the South Chicago Street Railway Co.

(2) Clean the contact surfaces of both halves of the field and file off the burs, if any exist, to secure perfect magnetic joints at the division of the yoke.

(3) Set the upper half of the field in position and secure it to the lower half by means of the field bolts and feather keys.

(4) Note that the machine is to be perfectly level along the axis of the shaft, except that when an oscillator is attached the machine is placed slightly out of level, as will be pointed out later.

Armature. Never try to support any of the weight of an armature by the commutator or collector rings. Do not allow these parts to rest on any blocking, and do not pass a rope around them for the purpose of lifting. When handling the armature always support it with a rope slung about the shaft, and be careful not to mar or scratch the shaft, as any roughness would cause it to cut the bearings and so produce heating when the machine is running.

In putting the armature in the field be careful not to scratch the bearings nor to bend the oil rings.

Coils. Assembly or field coils. The field coils of the larger machines are shipped separately. The coils are held on the poles by the dampers, which should be bolted to the pole pieces. The coils on each of the separate halves of the field should be properly connected before the machine is set up.

Each pole piece has a number stamped with steel stencil and also painted in red, and a red line is drawn parallel and near to one edge of the pole. This line and number correspond to similar marks inside the coil. In erecting, place the coils on the poles so that the marks coincide.

If a rotary converter has been exposed to dampness it may be dried out by employing one of the following methods:

(1) Short-circuit the field and apply to the collecting rings about 10 per cent of normal alternating current voltage, which may usually be obtained from the lowering transformers. During this application the d. c. brushes must be raised and the rotary must be at a standstill. The standard Westinghouse transformers are usually provided with taps between which a low voltage may be obtained.

(2) Run the rotary converter, driving it by a suitable motor, and short-circuit the armature on the direct current side with very weak field excitation. If shunt wound, separate excitation at very low voltage must be used. If the converter be compound wound, the armature may be short-circuited through the series field coils. As rotary converters are usually very sensitive as series machines this method should be undertaken only by those who are thoroughly experienced, as there is danger of excessive current.

(3) Dry the field coils from a source of separate excitation, with about two-thirds of the normal d. c. voltage. This will also dry the armature somewhat. While drying out, the temperature of the accessible parts should be watched closely, and not be allowed to exceed 75° C.

In drying out with current there is always danger of overheating the windings, as the inner parts may get injuriously hot because they cannot quickly dissipate the heat generated in them. Coils containing moisture are more easily injured by overheating than those which are already dry. Several hours, or even days, may be required for thoroughly drying out.

REPAIRS TO ARMATURE COILS.

Fig. 109 shows a section of the strap wound armature coils. The coils on the armature are either strap-wound or wire-wound. They may be arranged either in a trio circuit, or multiple type of winding. Care should be taken that the insulation be not abused, or it will not insulate. A blow upon a coil which forces one wire through the cotton insulation to the next wire will cause a short-circuit, and a bruise or bend in the insulating cell of an armature coil may cause a ground.

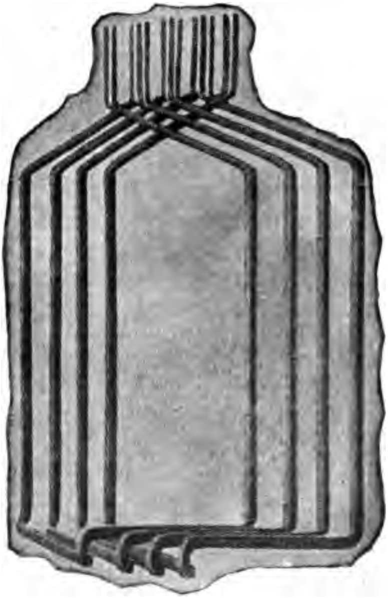


Fig. 109. Westinghouse Strap-Wound Rotary Converter Armature Coils.

If a defect in insulation appears on an armature coil, or on the outside of a field coil, it can often be repaired by carefully raising the injured wires, and putting fresh around them. The coils are held in place in the armature slots by means of wedges. In replacing a coil these wedges must be driven out from a sufficient number of slots to permit of the raising of the winding and the removal of the defective coil. The new coil can be placed in the slot, the wedges replaced and connections made as before. In lifting coils out of the slots care must be taken not to break or strain the insulation.

Commutator. This is a most important part of the machine and requires careful attention. Its surface should be kept smooth.

If the commutator is very rough it may be dressed up with a piece of sand stone, the proper quality to be determined by trial. The stone is held firmly in the hands and pressed against the commutator. After using the stone the smoothing of the commutator may be finished with No. 00 sandpaper. If the commutator is not very rough the sandpaper may be used alone. The use of emery cloth is not permissible on account of the grit it leaves on the commutator surface. It is advisable to raise the brushes when sandpapering the commutator.

Ordinarily the commutator only requires to be wiped off with a piece of canvas, but it should be kept lubricated by the use of a very small quantity of vaseline or oil applied with a piece of cloth. Do not use waste.

See that none of the segments of the commutator is at all loose.

If the commutator should get out of true it will be necessary to turn it down. This can be done while the armature is in its bearings by using a special slide rest and running very slowly, or the armature may be removed and the commutator turned down in a lathe.

Flat spots, or "flats" sometimes occur in a commutator, usually caused by excessive wear or by a loose bar in the commutator. At times a bad short-circuit may produce a flash that will start a "flat."

After long usage and much wear a commutator will sometimes get hot when carrying only normal load. This indicates that it is worn down about as far as it is safe to go and that it should be replaced by a new one.

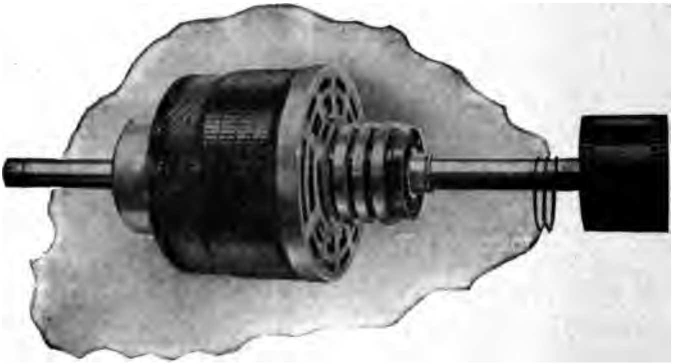


Fig. 110. Westinghouse Rotary Converter Armature from the Collector Side, 300 K. W., 550 Volts, Three-Phase.

Trouble in commutators is sometimes caused by the burning out of the mica insulation between bars. This may be due to several causes, the most common of which is oil-soaked mica or loose commutators which allow oil and particles of conducting material to work in between the mica and the bars.

It has rarely, if ever, been definitely traced to excessive voltage between bars although this is a cause commonly advanced. When this burning occurs it may be stopped and its effect remedied by scraping out the burnt mica and filling the space with a solution of silicate of soda (water-glass) or other suitable insulator. Trouble is also caused by high mica. This will start sparking which will burn the copper, thus aggravating the trouble. It may be remedied if caught in time by simply cutting the high mica 1/64 to 1/32 of an inch below the surface of the commutator. This can be done by means of any suitable cutter such as a hack-saw blade held between suitable guides.

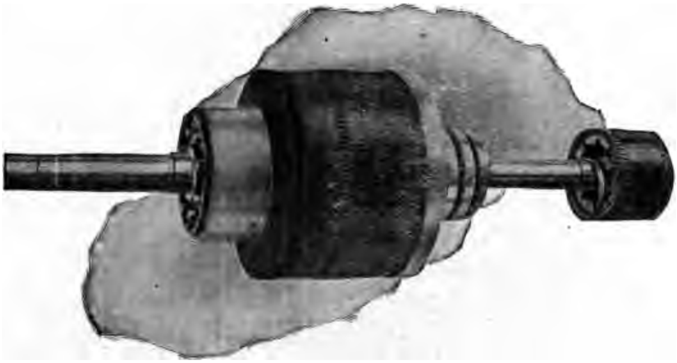


Fig. 111. Westinghouse Complete Rotary Converter Armature from the Commutator Side, 300 K. W., 550 Volts, Three-Phase.

Collector. The collector, in comparison with the commutator, requires little attention. It should nevertheless be given sufficient care to insure its running true and without being cut by the brushes. When cutting does occur it is frequently caused by the stiff brass piece on the back of the brushes bearing on the collector. The collector may be trued up with sandstone if it is not too much out of true. The operation of the collector can usually be improved by means of an oscillator.

Brushes. These are of carbon on the d. c. side and copper on the a. c. side. The position of the d. c. brushes when the machine is converting from alternating to direct current should be slightly in advance of the no-load neutral point on the commutator.

A dry brush of carbon sliding over copper is likely to chatter, and therefore brushes of the sliding type are liable to make more or less noise unless they receive proper attention. The noise can be avoided by keeping the commutator lubricated or by boiling the brushes in vaseline or dynamo oil. Boiling once in oil will last for a considerable length of time.

The brushes on machines having a swivel type of holder should be adjusted as follows:

(1) Arrange brush arms so that all are equally distant from the commutator face.

(2) Adjust carbons in holders so that the stops will allow ⅛ inch to 3/16 inch wear on the heels of the carbons.

(3) Grind the carbons with sandpaper until a good fit on commutator is obtained.

Carbon brushes should be equally spaced around the commutator. The best way to space them is to divide the circumference of the commutator into as many spaces as there are poles. This may conveniently be done by placing a strip of paper around the commutator exactly equal in length to its circumference and afterward dividing the strip of paper according to the number of poles in the machine. The paper may then be placed upon the commutator and the brushes set upon the spaces of equal division. This method is more accurate than that in which dependence is placed upon the uniform spacing of the bars.

Sparking.—Sparking at the brushes of rotary converters may occur from any one of the following causes.

(1) Brushes may not be on the proper point of commutation. They should always have a little forward lead without regard to the power factor at which the converter is running.

(2) Brushes may be wedged in their holders.

(3) Brushes may not fit the commutator surface.

(4) Brushes may not have sufficient pressure on the commutator.

(5) Brushes may be burned on the end, or covered with copper.

(6) Commutator surface may be rough. The commutator surface should be of a dark glossy appearance.

(7) A commutator bar may be loose, or may project above the others.

(8) There may be a "flat" on the surface of the commutator.

(9) The commutator may be dirty, oily, or worn out.

(10) The machine may be overloaded.

(11) There may be pumping or hunting.

(12) There may be high mica.

Bucking. Bucking is the expressive name given to the action of the rotary converter when arcing occurs between two adjacent brush holder arms, thereby short-circuiting the machine. Bucking is, in general, due to abnormally high voltage or a path of low resistance over the commutator surface or to abnormal commutation conditions. The poorer the commutation the more liable will the machine be to buck whenever these abnormal operating conditions occur. Some of the particular causes for bucking are the following:

(a) Rough or dirty commutator. A drop of water falling on the commutator has been known to cause the machine to buck.

(b) Excessive voltage due to increase in a. c. voltage.

(c) Excessive voltage due to static disturbances from lightning arrester short-circuits.

(d) Excessive voltage due to static discharge from or through lowering transformers. When bucking is due to this cause, it will usually occur when switching is done in the high tension circuits.

(e) Bucking may be caused by fluctuations in the voltage, due to the removal of a short-circuit.

In multiple wound rotary converters, balancing rings or cross-connections are employed as in direct current generators. These rings connect together points of equal potential around the commutator.

By this means the same field strength is obtained under each pole.

Oscillators. The armature of a rotary converter revolving with its horizontal shaft will take up normally a fixed position relative to its bearings, and the frame of the machine, and revolve without any tendency to move or oscillate in the direction of its length. This is detrimental to its best operation, as the brushes are liable to wear grooves in the commutator and collector.

The same is true of generator and motor armatures, although in a smaller degree, for the reason that these machines usually have some external force, belt, gear, or engine shaft, tending to produce a slight oscillation, while the armature of the rotary converter is free to remain in one position. It therefore becomes necessary to provide a means of producing a periodic movement of the armature shaft in the direction of its length, and this function is performed by the oscillator.

There are two classes of oscillators, viz.: mechanical and magnetic. The mechanical oscillator employed by the Westinghouse Co. is described as follows:

"This device is self-contained and is carried over one end of the shaft. The operating part consists of a steel plate grooved by a circular ball race in which travels a hardened steel ball. The steel plate is not quite parallel to the face of the end of the shaft. The normal position of the ball is at the lowest point of the circular race. The steel plate is backed by a spring.

The machine is leveled so that the armature is slightly inclined toward the oscillator. The steel plate is then adjusted so that when the ball is at its bottom position it just comes into contact with the shaft-end. As the armature revolves the ball is carried up the race, and, owing to the inclination of this race, compresses the spring. The reaction of the spring drives the shaft away. Thus the armature receives an impulse which moves it toward the other limit of its travel, and it continues to move until the opposing forces bring it to rest and start it back to its normal position, and where it again comes in contact with the ball and the operation begins over again.

Fig. 112 shows a diagrammatic view of the Westinghouse Magnetic Oscillator, of which the following is a description:

A magnet is mounted upon one of the bearing housings of the rotary converter in such a manner as to attract the end of the shaft. When the circuit is closed, the magnet draws the shaft toward it and when the circuit opens, the armature tends to resume its normal position which is determined by the leveling of the converter. The magnet has in series with it a make and break device called an interrupter which is controlled by a dash-pot to secure the proper frequency of action. As the dashpot offers an adjustable resistance the frequency of the impulses are adjustable. When there are a number of rotary converters in the same sub-station, the magnetic oscillators are connected in series and controlled by a single interrupter. Under certain conditions the commutator and collector surfaces of machines provided with oscillators may be worn in irregular wavy grooves. If this occurs it will be necessary to turn down the commutator and collector.

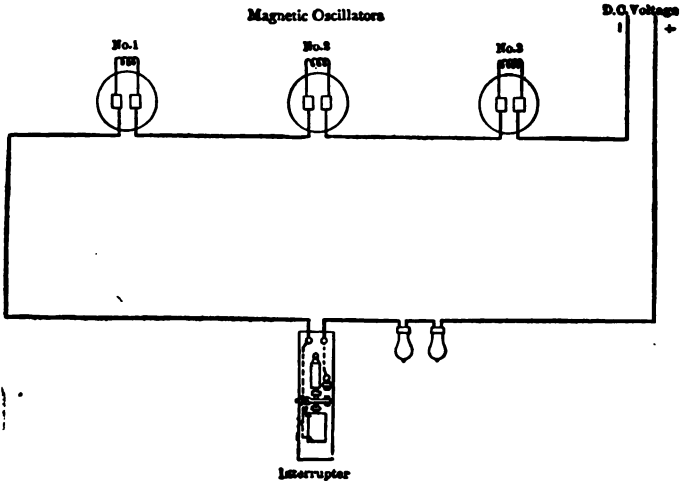


Fig. 112. Diagram of Connections for Magnetic Oscillator.

Figs, 104 and 105 show views of the Allis-Chalmers rotary converters, and the following is a brief description of their construction:

The field yoke, which is of the best quality of cast iron, is divided horizontally, and securely bolted together by fillister head screws, fitting into countersunk pockets covered by the name plates. This gives the machine a graceful and pleasing appearance.

The solid cast steel poles are securely bolted to the yoke, and can easily be removed without disturbing the armature. They have extended pole tips designed so as to distribute the magnetic flux over a large number of armature teeth, thereby reducing the iron loss and heating of that part of the machine, and also improving the commutation.

The armature core is built up of thin discs punched from very soft and specially prepared steel, of uniform quality, and high permeability. After punching, these discs are thoroughly japanned to prevent eddy currents. Special attention has been given to the proper ventilation of the armature; ventilating ducts are placed at frequent intervals throughout the core and the spider, and the ventilating spacers forming the ducts are designed so as to force a circulation of air through the armature. This results in low temperature and enables the machine to stand heavy overloads without injury. The coils are held in place by hardwood wedges.

The collector rings are made of copper and are liberally proportioned. They are designed so as to insure cool operation and are thoroughly insulated from each other and from the ground.

The armature coils are form-wound, and are absolutely interchangeable. The conductors are carefully insulated with the best material obtainable and the insulation is integral with the coil, no additional protection being required in the slots. All armature coils are subjected to a very severe puncture test in addition to the full load test, which is made when the machine is assembled.

The commutator segments are of pure hard-drawn copper and are carefully insulated with specially selected mica that wears evenly with the copper. The commutator is composed of a sufficient number of segments to keep the voltage between adjacent bars within conservative limits, and is designed to give a liberal contact surface for the brushes; sparkless commutation and freedom from flashing-over are thus secured.

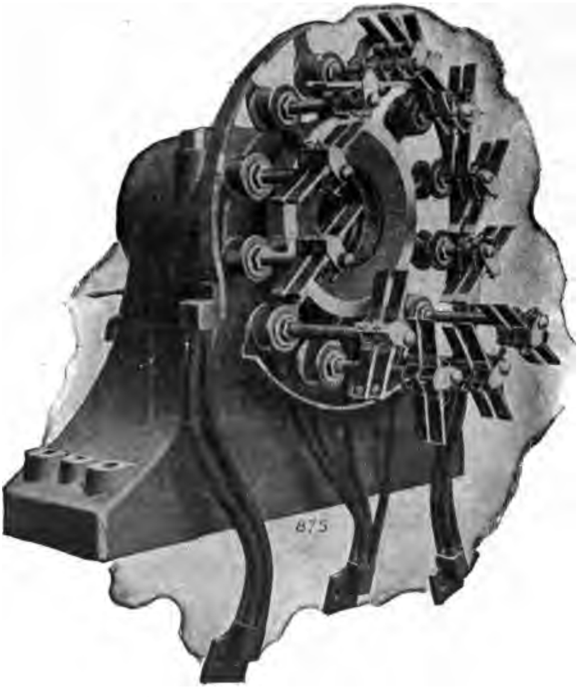


Fig. 113. Brush-Rigging and Brush-Holders on Alternating Current End of Allis-Chalmers 500 K. W. Rotary Converter.

The brush holders on the alternating current end (see

Fig. 113 are of the tangential type; copper gauze brushes are used, and the design of the brush holder is such that the pressure is uniform over the whole contact surface. The holders are attached to a cast-iron frame which is fitted to the bearing pedestal, on the alternating current end. The brush holders on the direct-current end are of the standard Bullock patented type; they permit of easy adjustment and removal of the carbon brushes and are mounted on heavy brass studs, supported by a cast-iron spider attached to the magnet frame of the machine. Provision is made for rotating the brush yoke so that the brushes can be easily adjusted to the position of best operation.

The bearings are designed with particular attention to large radiating surfaces. They are of the ball and socket type, and are both self-oiling and self-aligning.

Rotary converters are built either shunt or compound-wound, as desired. For railway systems in particular, where the car units are large in comparison with the capacity of the converter, compound winding is desirable, as otherwise the voltage will drop considerably whenever a car is started. The compounding should, as a rule, be such that with the prevailing conditions of the transmission line and transformers, regarding drop, reactance and regulation, the delivered voltage of the converters will be nearly constant for different loads and this voltage should be chosen as high as the car equipments will permit. There is of course no advantage in having a lower voltage at light loads.

In order to prevent the brushes from wearing grooves in the commutator, a slight oscillatory motion is imparted to the shaft, thus greatly prolonging the life of the commutator and keeping its surface in good condition. This motion, which in belted machines is automatically produced by the belt, is imparted to the armature shaft by the Allis-Chalmers oscillator.

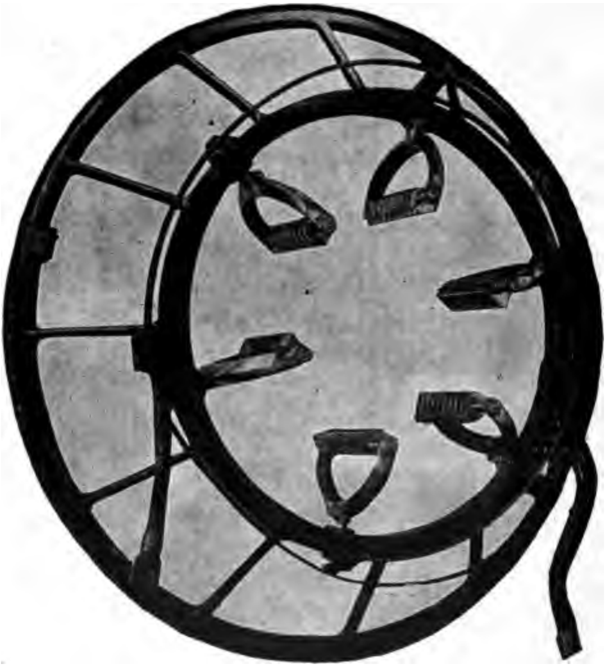


Fig. 114. Brush-Yoke and Brush-Holders Used on Direct Current End of 500 K. W. Allis-Chalmers Rotary Converters.

Hunting. The "hunting" of rotary converters has already been alluded to, but not enlarged upon. A rotary converter, and the generator supplying it with current may be likened in their speed relations, to an engine flywheel driving a second flywheel by means of a flexible coupling in which the driving force is transmitted through spiral springs. In this analogous mechanism the rotation of the second flywheel will be steady only as long as the rotation of the engine flywheel is steady; fluctuations in the rotation of the engine flywheel, will produce exaggerated fluctuations in the rotation of the driven wheel, due to the flexible nature of the coupling between the two wheels. The action of this mechanism may be explained more in detail as follows:

If the engine flywheel momentarily increases its speed, the second wheel will not maintain the same position relative to the engine flywheel as would be the case with two wheels rigidly connected together. The inertia of the driven wheel will cause it to lag behind the other in relative position, until the resulting tension in the springs is great enough to overcome the inertia, and momentarily increase its speed, bringing it back to its previous relative position. At the same time the tension in the springs reacts upon the engine flywheel so that the speed of this wheel is momentarily decreased if the engine will permit of a reduction in speed. If the inertia of the driven flywheel is large, the springs may take it beyond its initial position to a position relatively ahead of that of the engine flywheel, in which case the springs will be compressed, causing the second wheel to fall behind again, thus starting an oscillation in the rotation of this wheel. To set up this oscillation, three conditions are necessary: first, a variation in the regularity of the rotation of the engine flywheel; second, a flexible connection between the two wheels, and third, inertia in the second wheel.

In the electrical machines the action is very similar. If there is any irregularity in the speed of the generator the inertia of the armature of the rotary converter prevents it from instantly following the generator, and the result is a slight difference in the relative positions of the armatures of the two machines, thus causing a change in the phase positions of the generator E. M. F., and the converter counter E. M. F. This change in phase positions causes a difference in the instantaneous values of the two E. M. F.'s which in turn causes a so-called corrective current to flow between the two machines, and this current in its action is equivalent to the tension in the coupling springs in the mechanical arrangement of the two flywheels. This irregularity in the rotation of the rotary converter is called hunting and the means for preventing it are as follows:

The converter is provided with heavy copper grids that surround each pole face and extend across it imbedded in one or more slots. The form of these grids is shown in the illustration. The function of the copper grids is to act as dampers preventing the relative position of the converter armature from being changed by the corrective currents more than the initial change in the generator. The action is essentially a damping action and is the same as that of the copper magnet damper used in galvanometers and is analogous to the action of a dash-pot on an engine governor. If all the coupling springs in the flywheel arrangement already considered were provided with dash-pots the controlling action of the dash-pots would tend to prevent the "hunting" of the driven flywheel.

STARTING ROTARY CONVERTERS.

There are three usual methods of starting rotary converters.

(a) By a separate alternating current starting motor,

(b) By applying direct current to the commutator, the converter starting as a shunt motor.

(c) By applying alternating current directly to the collector rings, the converter starting as an induction motor.

(a) *Starting with separate alternating-current motor.* An induction motor is pressed on an extension of the armature shaft and this motor is used for bringing the armature up to synchronous speed. In order that the motor may bring the converter up to synchronous speed the motor is designed with a smaller number of poles than the converter and the resistance of the secondary rings is made such that when running the converter at synchronous speed and with normal field excitation the motor slip will be of such a value that the running speed of the motor will be the synchronous speed of the converter. It is not essential that this adjustment of slip be made accurately. If the speed is too high the slip may be increased by lowering the voltage or by increasing the load on the motor. The latter may be accomplished by connecting a rheostat across either the direct-current or alternating-current terminals of the converter.

With four-pole rotary converters it is not practicable to use a two-pole induction starting motor on account of the large slip that would be required. With four-pole converters, therefore, a single-phase series motor is used.

(b) *Starting from the direct current side.* For this method of starting direct current is obtained either from the regular service bus bars or from a separate generator or circuit and the converter is started as a shunt motor. If the converter is compound wound the series field coils must be short-circuited or the starting circuit must be connected inside of the series coils in order that changes in armature current will not exaggerate the changes in speed by changing the field strength.

The operation of starting is similar to that of any shunt motor. The converter is started with strong field and resistance in the armature circuit provided by a starting rheostat. The converter is brought into synchronism with the alternating current circuit by adjusting the speed by the field rheostat, and when synchronism is reached the converter is parallel with the alternating current circuit by throwing in the a. c. switches in the high-tension or low-tension side of the transformers as the case may be.

(c) *Starting from the alternating current side.* In this method the alternating current side of the converter is connected to the alternating current circuit, the direct current switches being open. Under these conditions the rotary converter starts as an induction motor, the armature acting as the primary and the field poles as the secondary. The field winding plays no part in starting, as it is open circuited in several places, by means of a break-up switch usually located on the side of the frame of the machine. It is necessary to open up the field winding into several sections in order to limit to a safe value the voltage induced in it by the rotating magnetic field set up by the polyphase current in the armature winding. This method is objectionable, and not to be pursued when it can *be avoided.*

SYNCHRONIZING ROTARY CONVERTERS.

When a rotary converter is started from the direct current side or by a separate starting motor, it must be in synchronism with the alternating current bus bars before it can be connected to them. Two machines, a generator and rotary converter, for example, are said to be in synchronism when their frequencies are the same and when their phase is the same. The two machines will have the same *frequency* when the numbers of alternations, or reversals of their E. M. F.'s in a given time are equal. This condition will be fulfilled when the product of the number of poles by the revolutions per minute for each machine is the same. The two machines will have the same *phase* when the positions of the armatures with respect to the field poles are the same, i. e., when similar armature coils are opposite positive field poles at the same instants. In addition to being in synchronism with the generator to which it is to be connected, the rotary converter must have approximately the same voltage as the generator as measured by a voltmeter.

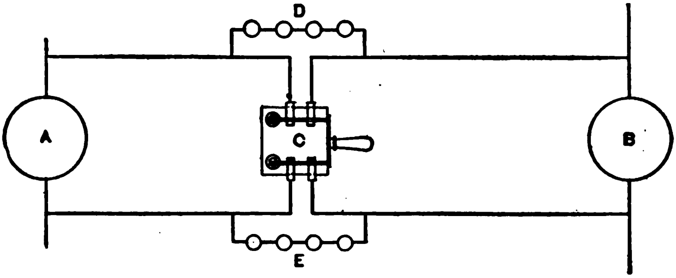


Fig. 115. Lamp Method of Synchronizing.

The operation of synchronizing a rotary converter with a generator consists in bringing the rotary converter up to approximately synchronous speed and to the same voltage as the generator, and then when the inevitable fluctuation in the speed of the two machines brings them in phase, in connecting them together. When the two machines have the same frequency, the same phase, and the same voltage, there will be no unbalanced E. M. F. and consequently no rush of current when the machines are connected together.

In synchronizing two machines it is evidently necessary to have some means for determining when the frequency and phase position of the incoming machine are right. The principle of the most common method of doing this is illustrated in Fig. 115.

A and B represent two single-phase machines or a single phase each of two machines, the leads of which are connected to the switch C, through two series of incandescent lamps, D and E. It is evident that as the relative positions of the phases of the electromotive forces change from that of exact coincidence to that of exact opposition the flow of current through the lamps varies from a minimum to a maximum. If the electromotive forces of the machines are in phase and of the same value, the current through the lamps will be zero. But as the difference in phase increases, the lamps will light up and increase in brilliancy until the maximum is reached, when the phases are in exact opposition. From this position they will decrease in brilliancy until dark indicating that the machines are in phase again. The rate of pulsation of the lamps depend on the relative frequency of the machines to be synchronized. If this rate is reduced to about one pulsation in ten seconds, ample time is allowed for closing the circuit.

The ideal synchronizer should perform three distinct functions:

(1) It should indicate whether the incoming converter is running too slow or too fast.

(2) It should indicate the amount by which an incoming converter is too fast or too slow.

(3) It should indicate the exact time of synchronism or coincidence in phase between the bus bars, and the incoming converter.

THE WESTINGHOUSE SYNCHROSCOPE.

This instrument is said to perform all of the above functions with perfection. The phase angle between the converter and generator is always equal to the angle between the pointer and its vertical position marked on the dial of the instrument. If the frequency of the incoming machine is higher than that of the line, this angle will vary, causing the pointer to rotate in one direction. If the incoming machine is lower in frequency, the pointer will rotate in the opposite direction. Fast and slow on the dial mean that the frequency of the rotary is higher or lower than the frequency of the line. When the frequency of the converter equals that of the line the pointer stops at some position on the scale, and when the converter is in phase with the line, the pointer coincides with the dummy pointer at the top of the scale. The main switch may then be closed. Two shunt transformers are necessary to connect the instrument to the bus bars, and one additional shunt transformer to connect it to each machine to be synchronized. When installed, the same shunt transformer may be employed in connecting other instruments to the bus bars and machines.

THE AUTOMATIC SYNCHRONIZER.

The uncertainty in synchronizing which arises from the hand-throwing of switches is done away with by the automatic synchronizer.

The instrument consists essentially of two solenoids, the upper ends of whose movable cores are flexibly connected to either end of a cross-beam pivoted at its center as an ordinary walking-beam. These solenoids are so connected that the one receives a maximum current at the instant of synchronism and the other receives a minimum current at the same instant. To accomplish this, the right-hand solenoid is connected in the same manner as a synchronizing lamp is connected to synchronize light, and the left-hand solenoid is connected like a lamp to synchronize dark.

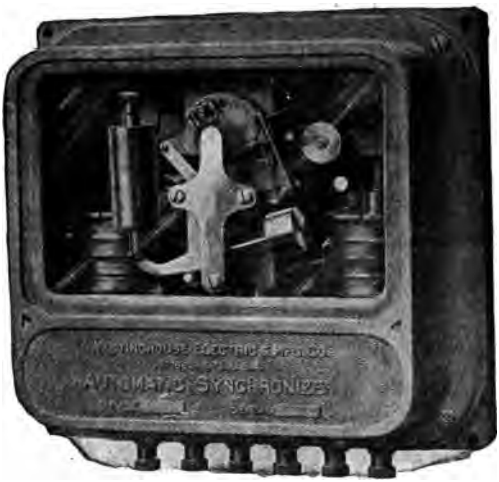


Fig. 116. View of Automatic Synchronizer, Case On.

Attached to the shaft of the cross-arm is a small contact finger or clip. This contact device is for closing a circuit through the relay switch which closes the circuit through the closing coil of an electrically operated switch at the proper moment of synchronism. The current for actuating the switch is taken from a source independent of the generators, such as the exciter. To the cross-beam is also attached one element of a dash-pot. The other element is connected through a system of levers to a disc of insulating material mounted on a short shaft in line with the pivot of the cross-beam. A small metal segment mounted on the disc is a little longer than the gap between the movable clip and a stationary clip, when the clips are at their minimum distance apart. Mechanical adjustment is made such that this minimum distance point is reached coincident with the point of synchronism. Reference to Fig. 117 will show how this dash-pot action on the disc prevents the movable clip from making contact

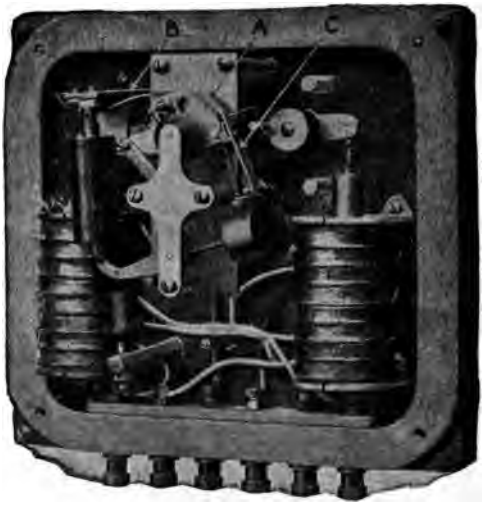


Fig. 117. View of Automatic Synchronizer, Case Off.

with the stationary clip when the rocking motion of the crossbeam is too rapid. Before the incoming machine has approached synchronism both of the solenoids are acted upon equally by currents from the synchronizing transformers and the cross-beam will assume a position midway between its two extreme positions. As the point of synchronism nears, the beam will begin to oscillate, following in its movements the variations in the currents. In one solenoid the current is a maximum while in the other it is a minimum, and vice versa. As soon as the oscillation becomes slow enough, the dash-pot is pulled out to its maximum length with the forward movement of the beam, and the contact piece on the insulating disc remains in the proper position to make the circuit between the moving and the stationary clips.

If the voltage of the incoming machine differs considerably from that of the bus bars to which it is to be connected, the device will not close the contact since the effect of the excessive voltage on the left-hand solenoid is to hold that end of the beam too low at the moment of synchronism. It is thus seen that the incoming machine will not be thrown in unless the voltages are approximately equal, the machine is in phase with the line, and the frequency is right.

A controller and relay switch are interposed in the circuit with the synchronizer and the electrically operated switch. By means of the controller switch the main or electrically operated switch may be tripped, but cannot be closed, as the closing coil is normally out of circuit, until the synchronizer is in the position assumed at the synchronous operation of the generators, or rotary converters, that is, when the solenoid of the relay is energized, and the contacts closed.

This closes the relay switch circuit, and completes the path of the current through the controller and electrically operated switches. The relay switch is provided with carbon break and relieves the contacts of the synchronizer from excessive currents.

For rotary converter work a simple form of electrically operated switch has been devised for use with the automatic synchronizing system, combining the functions of a switch and an automatic circuit-breaker, thus omitting the knife switches and fuses. As automatic switches require a certain period of time to close, it is necessary that the closing action begins in advance of the point of synchronism, in order that the switch will close at the correct time. This adjustment is easily made to suit any particular form of electrically, or pneumatically operated switch. The wiring of the various devices forms a complete interlocking system, preventing the coupling of machines under unfavorable circumstances, and avoiding the possibility of any resulting damage.

SYNCHRONIZING POLYPHASE CONVERTERS.

What has been said regarding the synchronizing of two single-phase circuits applies equally well to the synchronizing of the individual, and similar circuits of polyphase rotary converters.

PARALLEL OPERATION OF ROTARY CONVERTERS.

Direct current side. If several rotary converters are to supply current to the same direct current system they may be connected in parallel just like shunt or compound wound direct current generators. With compound wound converters an equalizing connection must be made between the different machines.

The load will be divided among the different converters according to their direct current voltages, as in direct current practice. The voltage may be regulated by changing the alternating current voltage as will be hereinafter described; or by regulating the field current, which changes the direct current voltage by increasing the drop in voltage in the armature; or by shifting the direct current brushes which changes the direct current voltage by collecting less than its maximum.

When one of two machines having strong series fields is carrying load, it may be found necessary in paralleling, to short circuit the series coils while throwing the machines together. The machine thrown in has its field strengthened by dividing up the load, and the other machine is weakened, thereby causing the flow of large currents between the machines. This extra current is liable to cause a disturbance which may reverse the polarity of the machine carrying the load as well as to cause a heavy rush of current in the alternating current feeder circuits.

Alternating current side. It is not advisable to have different rotary converters, supplying current to the same direct current system, connected together on the alternating current side, i. e., supplied from the same transformer secondaries. When this is done, a complete local circuit is formed by two converters and the alternating current, and direct bus bars, and any difference in the conditions of operation in the two machines—a slight difference in the relative positions of the direct current brushes of the two machines, for example—will cause large cross currents in this local circuit. The converters should be supplied by separate transformers or by separate secondaries when a single set of transformers is used.

GENERAL INSTRUCTIONS.

(1) When the converters flash over or the breakers come out due to excessive current, it is always wise to note the d. c. voltmeter before throwing in on the line again, as these troubles very frequently cause a reversal of polarity in the fields, making them build up in the opposite direction. If this should be the case, it will be necessary to reflash same as instructed elsewhere.

(2) When the a. c. power goes off for any reason, shut down the converter at once, opening all switches. By closing the synchronizing plugs the lamps will indicate when the power comes on again.

(3) When the a. c. breakers come out, open the d. c. breaker and switches, and then proceed to synchronize as in first starting.

(4) When a converter flashes over and is thrown out of circuit, it is best if possible to shut down for a moment and examine the commutator to clean up any burs which may have been caused on same. If this is not possible the commutator can be cleaned after the converter has been put in service by exercising the proper amount of care.

(5) Cleanliness is an important factor in the proper operation of all electric machinery, and proper care should be exercised on this point.

INSTRUCTIONS FOR OPERATION.

To Start a Single Converter with a Starting Motor.

(1) See that both the a. c. and the d. c. brushes are properly adjusted, and that everything is clear about the converter.

(2) See that all switches on the board are open on both the a. c. and d. c. sides, and that the resistance of the rheostat is all cut in the field circuit.

(3) Close the circuit breakers on the a. c. panel.

(4) See that the plugs to the synchronizing lamps, or synchroscope are in, and that the lamps burn dimly; also that the plug for the d. c. voltmeter is in.

(5) Start the rotary by closing the starting motor switch.

(6) Examine all oil rings on the converter to see that they are turning, and carrying oil.

(7) Build up the d. c. voltage to approximately the line voltage by cutting out resistance in the rheostat.

(8) Close the main a. c. switches to within an inch or so of the jaws, so that they may be thrown in quickly at the proper time.

(9) Note the lamps, and adjust the speed by means of the rheostat until the lamps dim slowly and regularly. When the lamps indicate the proper phase relation, (preferably when they are dark) close the a. c. switch. It is better to time your decision so that the switch will be closing as the lamps become dark, rather than when the converter is receding from synchronism.

It is sometimes necessary to shift the d. c. brushes back from the neutral point in order to get the proper speed.

(10) Open the starting motor switch.

(11) After the converter is synchronized adjust the field rheostat so that you get minimum current in the a. c. ammeters.

(12) Close the d. c. breaker and switches, and adjust the brushes to a non-sparking position.

To Start a Single Converter from the Direct Current Side.

Assuming the circuit breaker on the positive side, and the starting resistance across the negative switch.

(1) See that all switches are open and that the d. c. brushes are properly set, either on, or a little back from the neutral point. It is better to start with the series coil reversed, or at least cut out altogether.

(2) Close the a. c. breakers and synchronizing plugs.

(3) Close the d. c. breaker and the positive switch.

(4) Close the field switch having the resistance all cut out, and try the field poles to see that they are magnetized.

(5) Start the converter with the starting resistance, by cutting out same slowly. Close the negative switch. There should be in addition to the starting resistance a permanent resistance in the starting circuit.

(6) Examine oil rings to see that the same are turning, and carrying oil.

(7) Regulate the speed to the synchronous speed of the generator by means of the rheostat and synchronizing lamps. It is desirable though not necessary to have the a. c. voltage of the converter the same as that of the line. You may be aided to a slight extent in this adjustment by moving the brushes.

(8) When the voltage is correct and the lamps indicate the proper phase relation, close the a. c. switches.

(9) Adjust the rheostat for the minimum a. c. current and set the d. c. brushes at a non-sparking position.

To Start a Second Converter, to be Run in Parallel with Another.

(1) In starting a second converter to be run in parallel with another, follow the same procedure as in starting a single converter, using the synchronizing and meter plugs on the panel of the converter to be started.

(2) In building up the d. c. voltage make sure that it builds up in the same direction as that of the other rotaries, and the brush holders are in a similar position.

(3) Synchronize as usual by means of the lamps, and after having thrown the machine in, open the starting motor switch.

(4) In paralleling the d. c. side it is best to close the switches when the load on the first converter is a minimum. If the load on the converter having a strong series field is constant and heavy, it is better to short-circuit the series field on both converters, while throwing them together, otherwise the sudden dividing of the load may cause a rush of current between the machines and cause a reversal of polarity in the first converter.

(5) Regulate the a. c. by means of both rheostats to obtain the minimum.

(6) The proportions of the load may be regulated to a slight extent by shifting the d. c. brushes on the converters.

What to do When the Circuit Breaker Comes Out.

(1) If while operating, the d. c. circuit breaker comes out, first note the breakers and meters on the a. c. side, and see if everything is all right there. If so, open the switch on the same circuit with the d. c. breaker, or if the switches are connected, open all, then close the breaker

and afterward the switches. If the breaker continues to come out, have the trouble located and remedied.

(2) If only one a. c. breaker comes out and the machine stays in step it may be possible to open the switch under the same, and throw the circuit breaker in again quickly if everything else is right. It is advisable to note the ammeter on this circuit after closing same, to see if the line is open.

(3) If the a. c. breakers come out and the machine falls out of step open at once the d. c. breaker and all switches. It will then be necessary to synchronize the converter in the same manner as when starting.

(4) If two or more converters are running in parallel, and one falls out of step, first open the d. c. breaker on this converter to prevent the direct current from the other from feeding back. Then open all switches and synchronize as usual.

INVERTED ROTARY CONVERTERS.

A rotary converter running from direct current to alternating current has no longer a constant speed. When a rotary is driven by direct current, its speed follows the law of a direct-current motor and is governed by the strength of the field and therefore by the reaction of the armature current upon the field. When the alternating current load is inductive, changes of load may result in considerable variation in speed and, the converter is liable to reach an excessive speed if there is an application of a heavy inductive load. This may, however, be overcome by exciting the converter from a generator, the speed of which varies with that of the converter, particularly if the field of this generator is unsaturated at normal voltage.

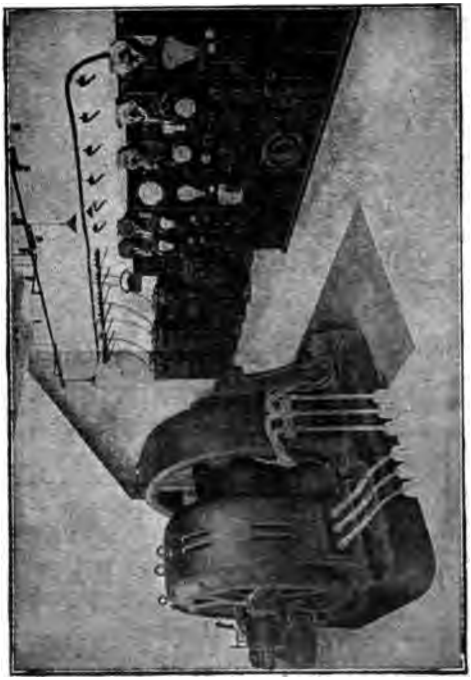


Fig. 118. Sub-Station.

Then any change in the speed of the rotary converter will cause a much greater change in the exciting voltage, and the field of the rotary converter will be changed. Thus the speed of the rotary will be independent of the amount or nature of the load. This is the method adopted by the Westinghouse Company.

When this method of exciting an inverted rotary converter is used, the converter is of the same size and proportion as a standard rotary converter of the same capacity. When self-excitation is used the inverted converter must be of larger size than a corresponding standard converter, so that the armature reaction may be made very small. There must also be provided an automatic speed-limiting device that will interrupt the power circuit in case the converter speed reaches a dangerous value.

With the inverted rotary converter one rheostat is connected in the converter field, and another in the exciter field. The rheostat in the converter field is used only in starting, and should be so connected in the circuit that when the converter is excited from the separate exciter, this rheostat is entirely out of circuit. The converter field should be connected to the exciter terminals with no resistance between them.

TREATMENT FOR ELECTRICAL SHOCK.

Writing in the Engineer and Mining-Journal, Richard Lee says:

There is a difference of opinion as to whether alternating-current, or continuous-current shocks, under certain conditions, are the more dangerous. It is well to remember, however, that a high-potential alternating circuit should not be regarded as safe to handle, even when the current has been shifted off, until it has been connected to earth and so practically discharged.

A live wire may often be handled without inconvenience when standing on an India-rubber mat, or on a dry-wood floor, but it is a safe rule to avoid contact with any part of an electrical apparatus, without thoroughly understanding what one is doing. The symptoms of an electrical shock are as follows: (1) Stoppage or weakening of the action of the nerves; (2) contraction and stiffening of the muscles; (3) stoppage or weakening of the action of the heart. The contraction of the muscles is what prevents the victim from letting go after grasping a live wire.

A person who has received a severe shock may become unconscious, and seemingly cease to breathe. None of these symptoms necessarily indicates death, and under no circumstances should remedial measures be abandoned until a physician has pronounced life extinct. It is most likely that many victims have been given up for dead after an electric shock, when the continuous application of further remedies might have restored them. A number of cases are on record where subjects who have received severe shocks have been unconscious for more than 30 minutes without the slightest discernible heart action, and still have recovered because of the artificial respiration applied.

In treating a victim, it is advisable to elevate the body and legs so as to send the blood to the brain, which action may prove a remedy for syncope, a condition often resulting from such a shock. If the heart has stopped beating, it is sometimes possible to start that organ again by applying a series of smart taps over the chest. The treatment should also be accompanied by drawing the arms in and out, so as to aid, or rather force artificial respiration. A number of authorities also advocate hypodermic injections of ether and alcohol beneath the skin, so as to distend the arteries, and help the heart action. In trying to disengage a man who is in contact with live metals, it is well to remember that dry clothing is a good insulator, and the best plan is to seize the victim's arm on the clothing and try to pull him away. Under no circumstances should the rescuer touch the bare skin, or take hold under the armpits where the clothing is apt to be damp.

SUGGESTIONS FOR RESUSCITATION FROM APPARENT DEATH FROM ACCIDENTAL ELECTRIC SHOCKS.

Augustin H. Goelet, M. D., in The Electrical World: The urgent necessity for prompt and persistent efforts at resuscitation of victims of accidental shocks by electricity is very well emphasized by the successful results in the few instances recorded. In order that the task may not be undertaken in a half-hearted manner, it must be appreciated that accidental shocks seldom result in absolute death, unless the victim is left unaided for too long a time, or efforts at resuscitation are suspended too early.

In the majority of instances the shock is only sufficient to suspend animation temporarily, owing to the momentary and imperfect contact of the conductors, and also on account of the indifferent parts of the body submitted to the influence of the current. It must be appreciated also that the body under the conditions of accidental shocks seldom receives the full force of the current in the circuit, but only a shunt current, which may represent a very insignificant part of it. When an accident of this nature occurs, the following rules should be promptly adopted and executed, with due care and deliberation:

1. Remove the body at once from the circuit by breaking contact with the conductors. This may be accomplished by using a dry stick of wood (which is a non-conductor), to roll the body over to one side, or to brush aside a wire, if that is conveying the current. When a stick is not at hand, any piece of dry clothing may be utilized to protect the hand in seizing the body of the victim, unless rubber gloves are convenient. If the body is in contact with the earth, the coattails of the victim may be seized with impunity to draw it away from the conductor. When this has been accomplished, observe Rule 2.

2. Turn the body upon the back, loosen the collar and clothing about the neck, roll up a coat and place it under the shoulders, so as to throw the head back, and then make efforts to establish artificial respiration (in other words, make him breathe), just as would be done in case of drowning. To accomplish this, kneel at the subject's head, facing him and seizing both arms, draw

them forcibly to their full length over the head, so as to bring them almost together above it, and hold them there for two or three seconds only. (This is to expand the chest and favor the entrance of air into the lungs.) Then carry the arms down to the sides and front of the chest, firmly compressing the chest walls, and expel the air from the lungs. Repeat this maneuver at least sixteen times per minute. These efforts should be continued unremittingly for at least an hour, or until natural respiration is established.

3. At the same time that this is being done, some one should grasp the tongue of the subject with a handkerchief or piece of cloth to prevent it slipping, and draw it forcibly out when the arms are extended above the head, and allow it to recede when the chest is compressed. This maneuver should likewise be repeated at least sixteen times per minute. This serves the double purpose of freeing the throat so as to permit air to enter the lungs, and also, by exciting a reflex irritation from forcible contact of the under part of the tongue against the lower teeth, frequently stimulates an involuntary effort at respiration. If the teeth are clenched and the mouth cannot be readily opened to secure the tongue, force it open with a stick, a piece of wood, or the handle of a pocket knife.

While this is being done a physician should be summoned, who, upon his arrival, can best put into practice Rules 4 and 5 in addition to the foregoing, should it be necessary.

4. Forcible stretching the sphincter muscle controlling the lower bowel excites powerful reflex irritation and stimulates a gasp (inspiration) frequently when other measures have failed. For this purpose the sub-

ject should be turned on the side, the middle and index fingers inserted into the rectum, and muscles suddenly and forcibly drawn backward toward the spine. Or, if it is desirable to continue efforts at artificial respiration, at the same time the knees should be drawn up and the thumb inserted for the same purpose, the subject meanwhile retaining the position on the back.

5. Oxygen gas, which may be readily obtained at a drug store, if the accident occurs in a city or large town, is a powerful stimulant to the heart if it can be made to enter the lungs. A cone may be improvised from a piece of stiff paper and attached to the tube leading from the tank, and placed over the mouth and nose, while the gas is turned on during the efforts at artificial respiration.

It is both useless and unwise to attempt to administer stimulants to the victim in the usual manner by pouring it down his throat, therefore this should not be attempted.

AIR BRAKES.

With the advent of the heavy motor cars, the air brake has to a great extent supplanted the hand brake. The straight air and the automatic air are the two systems now generally used. The straight air is employed principally on single motor cars, and in some instances on short trains. The automatic air, as its name indicates, applies the air automatically and will operate on two sections of a train which may happen to break in two. This brake has been in general use on steam roads for a number of years. In one method for supplying the compressed air each car is equipped with a small compressor and a small reservoir. The compressor is driven by an electric motor which maintains automatically sufficient compressed air in the reservoir to operate the brake. The motor is cut in and out of the circuit automatically by means of a governor actuated by the rise and fall of the pressure in the reservoir.

The operation of the automatic and straight air brake systems are essentially different, the principle involved in the application of one system being just the reverse of that involved in the application of the other. With the straight air brake system, the air is admitted to the train pipe in order to apply the brakes; and to release them, the air is allowed to escape; whereas with the automatic brake system, in order to set the brakes the air is allowed to escape from the train pipe and to release them the air is admitted again; and with this brake the automatic train pipe is always under pressure, except in emergency applications, and when the brakes are released the pressure is greatest. With the straight air brake equipment, on the contrary, the train pipe is only under pressure when the brakes are applied. In the automatic system, each brake cylinder has its own reservoir in which the air is stored for its own use exclusively, and this reservoir is called the auxiliary reservoir. The train pipe and auxiliary reservoirs are supplied with air from a main reservoir which receives the compressed air directly from the compressor.

This brake is controlled by a triple valve composed principally of a slide valve and a piston. The brake is applied directly by the air passing into the brake cylinder from the auxiliary reservoir, and which is effected by a reduction of the air pressure in the train pipe, which causes the greater pressure of the air stored in the auxiliary reservoir to push the piston, which in turn opens the slide valve and permits the air in auxiliary reservoir to enter the brake cylinder. Instantaneous application of the brakes may be had throughout the train by a sudden and heavy reduction of the air in the train pipe, which causes auxiliary valves to open through which the air from the train pipe enters the brake cylinder, thereby increasing by about 1/5 the pressure which the brake cylinder would derive from the auxiliary reservoir only. The release of the brakes is effected by just the contrary action of the air in the train pipe. When the reduced air pressure in train pipe which, primarily caused the setting of the brakes, is restored again to normal and is greater than the pressure in the auxiliary reservoir, the piston is pushed back again to its normal position, the slide valve closes and the communication between the train pipe and auxiliary reservoir is re-established; the air in the brake cylinder escapes through the triple valve exhaust port and the brakes are released, and at the same time the auxiliary reservoirs are recharged.

To apply the brakes the handle of the brake valve is moved to the right, and to release the brakes the handle is moved to the extreme left. When the handle is at the right-hand position, communication with the main reservoir is cut off, and the air pressure in the train pipe is reduced by a part of the air escaping to the outside atmosphere. When the handle is at the extreme left-hand position the air pressure in the train pipe is re-established by a supply from the main reservoir.

In emergencies, or in case of accident the pressure in the train pipe may be immediately reduced and the brakes applied by utilizing what is known as the "conductor's valve." This is a supplementary device which may be used with this system. It is operated by a cord passing through the car which when pulled opens the valve and permits the air to escape from the train pipe. At all times this valve must be kept closed, except when necessary to apply the brakes by its use. The principle upon which the brakes are operated by this system lies essentially in the reduction and increase of air pressure in the train pipe and, therefore, any rupture of the pipe, by parting of the train or from any other irregularity, is sure to cause an automatic application of the brakes. Without some means to prevent the escape of air from the train pipe, and the consequent reduction of air pressure when separating the couplings between the cars, the brakes would be applied. To provide against such untoward contingency the train pipe at each end of the car is equipped with an angle cock which when closed prevents the escape of air from the pipe or hose. To provide against any obstacles to the operation of a train which would be offered by reason of the brake apparatus of any one car being disabled, the cross-over pipe leading from the train pipe to the quick action triple valve, is provided with a cut-out cock by means of which the brake apparatus of the disabled car can be cut out or rendered inoperative. In the train pipe near the motorman's valve another cut-out cock is provided, which serves to cut out the motorman's brake valve on all motor cars except the first, where the train is composed of several cars.

In the straight air system the air is allowed to pass through the train pipe from the main reservoir to the brake cylinder when the brake is applied; but when the brake is off the pipe is empty. To release the brake the train line must be opened to the atmosphere by the motorman in order that the air confined in the brake cylinders may escape through it.

In the automatic air system the pressure in the reservoirs under each car in the train is maintained by the pressure in the train pipe which is constant. Submitting to this principle the brakes can be applied to the whole train by any diminution in the train line pressure. The bursting of hose between the cars; the use of the emergency valve in any car; or the use of the brake valve by the motorman, will cause the reservoir in each car, by means of the automatic triple valve, to supply the air to the brake cylinder of each car, which brings the train immediately under control. To recharge the reservoirs to the proper pressure and release the brakes, the air is admitted by the motorman to the train pipe from the main reservoir.

HOW TO OPERATE AUTOMATIC AIR BRAKES.

To test the brakes when a train is made up the motorman should proceed as follows: Place the brake valve handle in running position and charge the train line and auxiliary reservoirs. Then place the brake valve handle in lap position and when the black hand of the duplex gauge falls the charging is complete; then move the handle of the brake valve to the service application notch to obtain a reduction of 10 lbs. in the train line. Now place the brake valve on lap, remove the handle, and examine the cylinder of every car in the train and if the position of each piston indicates that the brakes on all the cars are firmly set, release the brakes from the rear of the last car and proceed again along the length of the train to the front and see that all brake shoes have been released and hang freely. Except when an emergency requires it, or when making a test, it is advisable not to use more than seven pounds for the first reduction, and after that reduction not more than four pounds at any one reduction. The brakes can be sufficiently applied by a reduction in train line pressure of about 15 lbs., as this amount of reduction equalizes the auxiliary reservoir and brake cylinder pressures, and any further reduction in making a service application will cause a waste of air, resulting in retarding the release of the brakes, in overtaxing the compressor, and in jarring stops. When stopping a train two applications of the air are preferable to one, as the train can be brought to a standstill with greater accuracy, with a lighter reduction of pressure on the second application, and prevents the skidding of wheels, and the shock attending the too sudden checking of speed. When a second application is to be made in a service stop, move the brake-valve handle to the full release and return it promptly to the lap position. When the train is brought to a stop, move the handle to full release until full train line pressure is restored and then return handle to running position. To avoid the backward pitch accompanying a too sudden service stop ease up a little on the brakes just before the stop is made. A little practice in this particular will enable the motorman to estimate accurately the time to slightly release the brakes before the car is brought to a standstill.

Do not reverse the motors except in case the brakes fail to operate, or in an emergency, where a failure to do so would endanger life or cause more serious damage to property. In most emergencies the train may be stopped in very short distance by throwing the handle to the full emergency position and hold there until the stop is made. Should it become necessary, however, to reverse the motors, throw the reverse handle in the contrary direction and move the controller handle to the second notch.

Should a train-line hose or train pipe burst or should the train part, the brakes will be automatically set. In an accident of this nature, the train can still be handled until the breakage has been repaired, by closing the train-pipe cock just ahead of the break and by opening the release valves in the auxiliary reservoirs to the rear, which will release the brakes which they actuate. The brakes ahead of the closed train pipe will then be under control of the motorman. To provide for a prompt release of the brakes in a case where they apply without any assignable cause, place the brake valve handle in lap position which prevents loss of reservoir pressure and insures prompt release of brakes when the motorman receives the signal to release them.

In the brake equipment of some cars the foundation rigging is so constructed that the power and hand brakes pull against each other so that if the air brake is applied and the hand brake is set up, the brakes will become released by the leaking off of the air brake; therefore the motorman must see that the air brake is released before setting the brake on cars which are to be set off, and no car should be set off without closing the train-pipe cocks, parting the hose and hanging them up securely.

ELECTRIC RAILWAY TROUBLES AND HOW TO FIND THEM.

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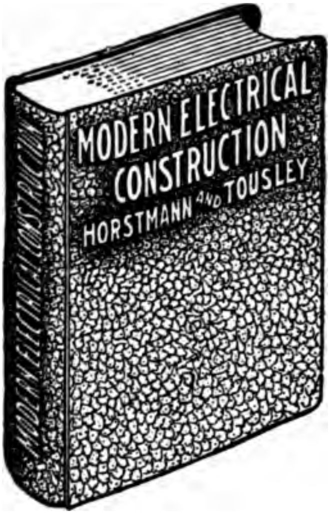
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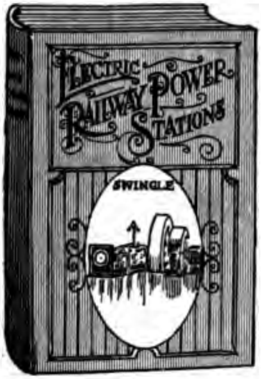

THE Central Station, with its modern appliances for the economical consumption of fuel, and the production of heat, its machines of various types, such as steam engines (both reciprocating and turbine), gas engines of all kinds, and other forms of prime movers, by means of which this heat is transformed into energy or power capable of turning the dynamos, which in turn transmit this power in the form of electrical energy, to where it is needed to do the work, will be the subjects treated upon in the following pages, in a plain, practical manner, from the standpoint of the operating engineer rather than the designer, although the important topics of design and construction will receive some attention also. In this age of progress along the lines for the betterment and welfare of the human race, electricity, and electrical engineering occupy positions in the front rank. It therefore behooves all, but especially the engineer who would keep abreast of the times, and time his steps to the march of improvement, to keep well posted on all details connected with the economical production of electrical energy in the power station, and its distribution from thence to distant localities, where through the medium of suitable apparatus, the work is performed. It has been the earnest endeavor of the author to furnish the seeker after knowledge with a complete collection of reliable and up-to-date facts, and details in connection with the installation and operation of central power stations. The very latest standard appliances for producing power, through the medium of steam, gas and electricity, will receive due attention, according to their merits. Special efforts have been put forth to collect data with reference to gas engines of large capacity. The subject of fuel is becoming daily more important. Any appliance that will produce the maximum amount of heat-energy from the minimum weight of coal, is destined to be the favorite, and this appears to be the position occupied by the gas engine today. This subject is therefore treated at length. Dynamos, switch boards and all the various apparatus are given due consideration in every detail.

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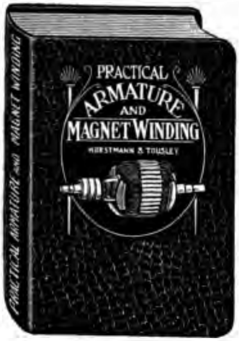

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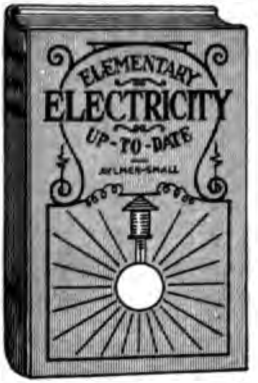

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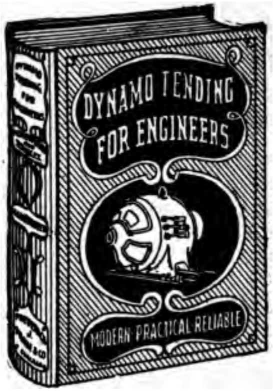

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